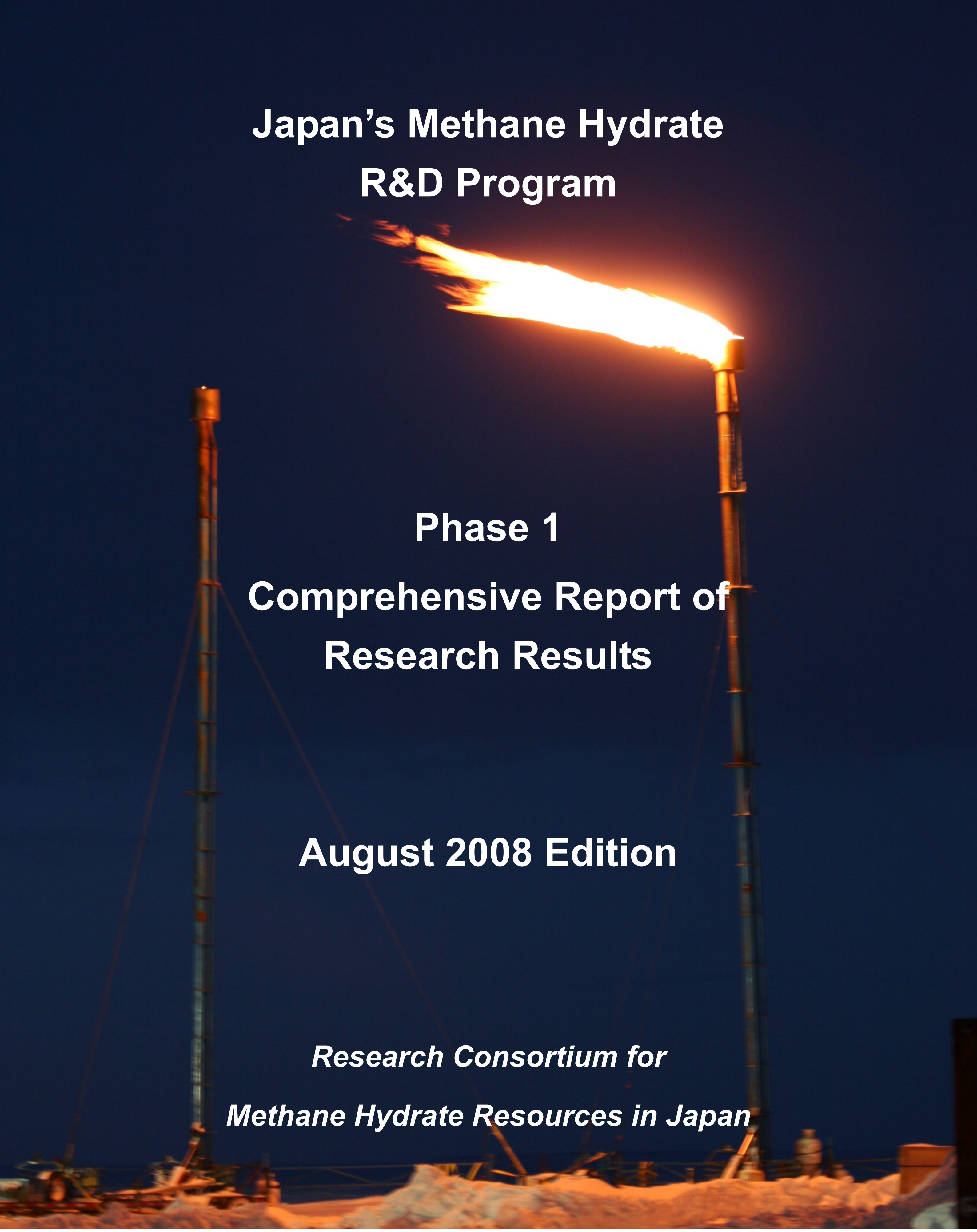

Japan's Methane Hydrate R&D Program

Phase 1

Comprehensive Report of Research Results

August 2008 Edition

Research Consortium for

Methane Hydrate Resources in Japan

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Contents

1. Highlights of Phase I Accomplishments

Continuous efforts have been made to elucidate the characteristics of pore filling type methane hydrate bearing sediments in marine environments and to execute our responsibility as one of the front runners in methane hydrate research.

(1) Success of continuously methane gas production from subsurface methane hydrate-bearing zones.

- Methane hydrate-bearing zones have been recognized in subsurface layers of the Arctic region for approximately 40 years.
- As the world's first attempt, we succeeded in producing methane gas continuously by dissociating methane hydrates that saturate the sandstone layers at depths of approximately 1,000m below the surface in Canada.
- Both the hot water circulation method (2002) and the depressurization method (2007 and 2008) were successfully conducted to produce methane gas, and the depressurization method was proven to be effective as a production method that could be utilized in future.
  See article 6. Achievements of the Onshore Gas Hydrate Production Test.

(2) For the first time in the world, turbidite sand and mud alternation layers were discovered in the eastern Nankai Trough area, which were considered viable and prosperous for developing methane hydrates resources.

- The occurrence of methane hydrate filling pore spaces of sand layers offshore was revealed for the first time through the drilling of the MITI Exploratory Test Well "Nankai Trough" in FY 1999. Those sand layers were also confirmed to be turbidite sand and mud alternation layers through the drilling of METI Exploratory Test Wells "Tokai-oki to Kumano-nada" in FY 2003.
- The technique of picking out the methane hydrate concentrated zones which were the alternations of sand and shale composed of sand layers with high methane hydrate saturation has been established.
  See article of 5.1. Objective 1: .

(3) Experimental testing methods of core samples obtained from methane hydrate-bearing layers and associated layers at the in-situ conditions were established.

- The occurrence and properties at the in-situ conditions of turbidite sand and mud alternation layers were elucidated.
- Improvements of the PTCS (Pressure-Temperature Core Sampler) system originally developed in Japan contributed somewhat to the retrieval of layer samples while maintaining the in-situ pressures and temperatures.

See article of 8.2. Physical Property Measurements of Methane hydrate-bearing layers (2. Modeling Section) and 10.2. Laboratory Facilities of Core Testing.

(4) In a world first, the probabilistic method based on the well data and seismic data calculating the volume of resource of methane gas contained in methane hydrate-bearing layers was established, and the amount of gas trapped in the eastern Nankai Trough area was estimated with this method.
See article of 5.2. Objective 2: Assessment of methane gas amounts in promising methane hydrate bearing offshore areas.

(5) The Japan's own simulator dedicated to evaluating the production behaviors of methane gas from methane hydrate-bearing layers was developed.
See article of 7. The Production Simulator.

2. Methane Hydrate

Methane hydrate is one of a number of unconventional natural gas resources. It is an ice-like white solid form that is composed of water and methane gas, and is sometimes called fiery ice. Methane hydrate is stable in a limited range of pressures and temperatures (stability field), as indicated in Figure 2-1.

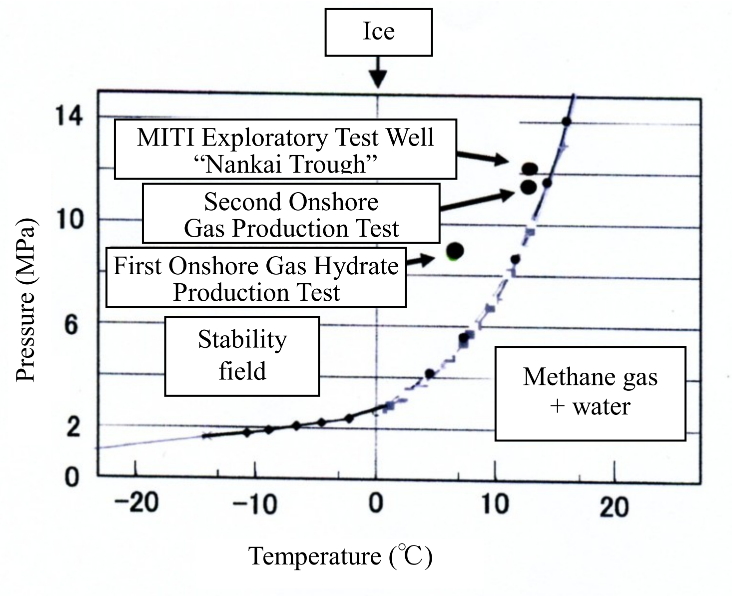


Figure 2-1 Stability field of methane hydrate

Methane hydrate crystals are usually comprised of two kinds of polyhedral structures, of which the smaller one is shown in Figure 2-2. Each methane molecule is contained in a cage of water molecules.

Methane hydrate consists of numerous cages that do not always contain all methane molecules. In occasional cases, some cages are empty. The ratio of methane molecule occupied cages is indicated as the methane cage occupancy. According to recent studies, cage occupancy of natural methane hydrate ranges from 0.9 to 0.95.

One m^3 of methane hydrate would dissociate to $0.8m^3$ of water and methane. The volume of methane becomes to $172m^3$ (0°C, 1atm) when the cage occupancy is 100%. It usually ranges from 155 to $165m^3$ depending on the cage occupancy, and may be $165m^3$ on average.

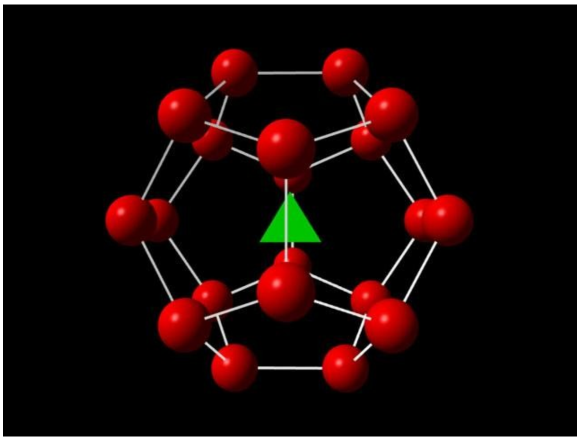


Figure 2-2 A small cage composed of the crystalline structure of methane hydrate

Green: methane molecule Red: water molecule

Methane hydrate offshore exists in a variety of shapes and occurrences.

Figure 2-3 shows the sandy core obtained from the formation at the depth of 164.3m below seafloor in METI Exploratory Test Wells “Tokai-oki to Kumano-nada” of which water depth is 720m. Methane hydrate fills the intergranular pore spaces among sand grains. Gas is trapped in pore spaces of the conventional natural gas layers, but the pore spaces of methane hydrate-bearing layers are occupied by methane hydrate instead of gas. When methane hydrate dissociates, gas and water may fill the pore spaces in a way similar to that of conventional natural gas layers. Those methane hydrate-bearing sandy layers are the target of the exploitation of methane hydrate.

Figure 2-3 A core from the sandy methane hydrate-bearing layer

Figure 2-4 shows a sample of massive methane hydrate contained in a muddy sediment obtained from a depth of 126m below the seafloor at the Kumano-nada offshore in METI Exploratory Test Wells “Tokai-oki to Kumano-nada” where water depth is 1,862m. Such an occurrence is recognized in marine environments worldwide, and is considered low in the order of priority for exploitation compared to methane hydrate existing in sandy sediments.

Figure 2-4 A massive sample of methane hydrate in muddy sediment

Figure 2-5 shows an example of massive methane hydrates exposed on the seafloor, which was discovered at a water depth of 545m in the Gulf of Mexico, in the United States. This is not white in color due to it containing impurities, and it has been discovered on seafloors around the world. It was also discovered in the southwest offshore of the Sado Island in Japan, and is considered low in the order of priority for exploitation compared to methane hydrate existing in sandy sediments.

Figure 2-5 A methane hydrate exposure on the seafloor
(Fire in the Ice, Winter 2004)

3. Japan's Methane Hydrate R&D Program and Implementation Structure of Phase 1

3.1 Japan's Methane Hydrate R&D Program

According to the accomplishments of the MITI Geophysical Exploration "Nankai Trough" in FY 1996 conducted by METI and the MITI Exploratory Test Well "Nankai Trough" in FY 1999 that was undertaken based on the results of "drilling of a methane hydrate research well in Mackenzie delta, Canada" in FY 1998, the result confirming the existence of methane hydrate layers in marine sandy sediments was obtained for the first time in the world. Therefore, there is a possibility that methane hydrate deposits may be able to be used as an energy resource.

Japan's Methane Hydrate R&D Program (hereafter called "the R&D Program") (July, 2001) was organized from a medium- to long-term viewpoint of aspiring to find solutions to various issues regarding the economical extraction and utilization of methane gas from methane hydrate-bearing layers.

The relevant articles in the R&D Program are quoted below.

"Japan's Methane Hydrate R&D Program"

I. Objectives
Methane hydrate, of which there is expected to be substantial amounts offshore Japan, is positioned as a future energy resource, and impelling technological developments into drilling and production of methane hydrate on an economical basis for future utilization will contribute to the acquisition of a long-term steady supply of energy.

II. Goals of the Methane Hydrate R&D Program
In order to improve technologies for the commercial production of methane hydrate distributed offshore Japan, the following goals have been configured. To help turn the plan into reality, efficient technological developments will be promoted in conjunction with ideas from international collaborations. This scheme and associated achievement will be reflected in government energy policy.

1. Clarification of MH occurrences and characteristics offshore Japan
2. Assessment of methane gas amounts trapped in promising methane hydrate bearing offshore areas
3. Selection of methane hydrate resource fields from promising methane hydrate bearing offshore areas and deliberation of economic potential
4. Implementation of production test in the selected methane hydrate resource fields (until FY 2011)
5. Improvement of technologies for the commercial production (until FY 2016)
6. Establishment of a development system complying with environment

III. Road map for achievement of goals
The road map and prioritized technological issues to accomplishment the above goals are described below. In addition, the scheme will be advanced by investigating specific technology development items and implementation structure.

1 Targets for developing methane hydrate resources
- (1) Occurrences expected
  - 1) Occurrences in sandy sediments (unconsolidated sand sediments and sandstone sediments)
    - a. Methane hydrate-bearing layers
    - b. Methane hydrate-bearing layers and associated free gas layers beneath
      Gas phase is network-saturated and has effective permeability
  - 2) Occurrences in sedimentary formations other than sandy sediments
- (2) Targets for development
  In this plan, occurrences of methane hydrate in sandy sediments should be near-term targets for exploitation.
  Methane gas contained in hydrate is expected to be mainly biogenic, however, the presence of thermogenic gas should be noted.

(the rest is omitted)

We have targeted methane hydrate contained in sandy sediments for research and development for Phase 1. Each of the items in the goals in the R&D Program is allocated to Phases 1 to 3 as follows.

1. Clarification of MH occurrences and characteristics offshore Japan
   According to the findings obtained from the eastern Nankai Trough area till FY 2006, we will investigate the existing seismic data offshore Japan. In Phase 1 we have principally targeted the western Nankai Trough and southwest offshore of the Sado Island in addition to the eastern Nankai Trough area. We re-examined the BSR distributions in offshore Japan, and identified areas that were potentially methane hydrate concentrated zone.
2. Assessment of methane gas amounts trapped in promising methane hydrate bearing offshore areas
   We developed a probabilistic method to calculate the volume of resource of methane gas trapped in methane hydrate contained in sandy sediments especially in the eastern Nankai Trough area. Future tasks remain to be carried out for other areas.
3. Selection of methane hydrate resource fields from promising methane hydrate bearing offshore areas and deliberation of economic potential
   We developed a method to select methane hydrate resource fields in the eastern Nankai Trough area, and implemented it. We also evaluated the economic potential in a section of those areas.
4. Implementation of production test in the selected methane hydrate resource fields (until FY 2011)
   Although this item was supposed to have been implemented in Phase 2, necessary technologies for the offshore production test in the methane hydrate-bearing layers were partially researched and developed in Phase 1.

5. Improvement of technologies for the commercial production (until FY 2016)
   This item is expected to be implemented in Phase 3.

6. Establishment of a development system complying with environment
   Fundamental data about the natural environment in the eastern Nankai Trough area where the offshore production test is expected to be carried out are examined in Phase 1. We began to research and develop technologies to establish a development system complying with environment in Phase 1, which will be continued to the end of the R&D Program.

FY limits of time specified in the items 4 and 5 are the future tasks that remain to be carried out.

Phase 1 was initially planned for six years from FY 2001 to FY 2006. However, a two-year extension was demanded by the following reasons; (1) It became clear through METI Exploratory Test Wells "Tokai-oki to Kumano-nada" (FY 2003) that methane hydrate of the eastern Nankai Trough existed in sandy sediments of alternating beds of sand and mud, (2) Depressurization method was suggested as an efficient production method at the methane hydrate-bearing layers and, (3) Optimal design to realize the depressurization method in the production test was required. Evaluations and admonishments from the Advisory Committee for Promotion and Evaluation of National Methane Hydrate R&D Program, the Evaluation Subcommittee of Industrial Technology Sectional Committee of Industrial Structure Council and the Council for Science and Technology Policy Expert Panel on Evaluation conducted in FY 2005 allowed Phase 1 to be extended by two years. Therefore, Phase 1 was amended for eight years from FY 2001 to FY 2008 (refer to Figure 3-1).

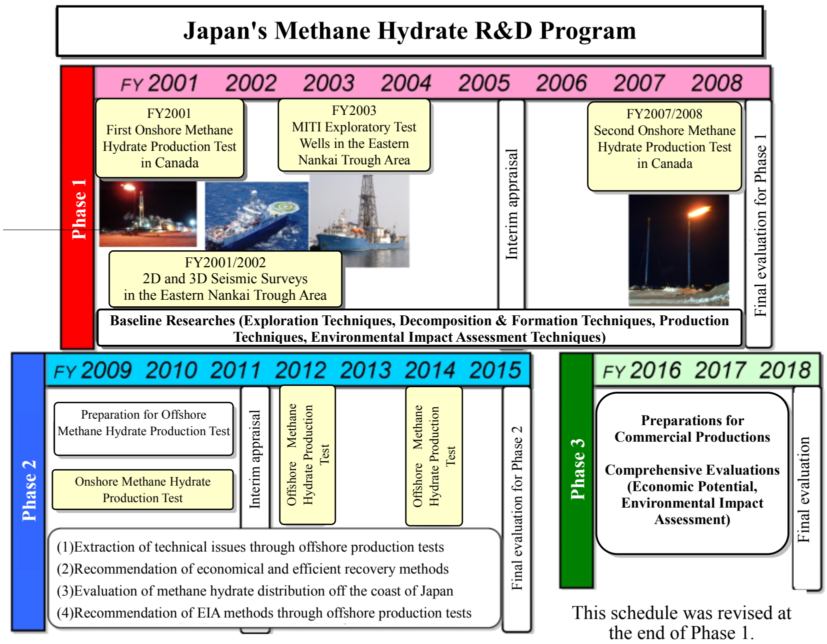


Figure 3-1 "Japan's Methane Hydrate R&D program": Schedule
(the Phase 1 after amendment of a two-year enlargement)

3.2 Implementation Structure of Phase 1

"Research Consortium for Methane Hydrate Resources in Japan" (abbreviated name: MH21 Research Consortium) was set up to attain the goals of Phase 1. Three organizations comprising Japan Oil, Gas and Metals National Corporation (JOGMEC), the National Institute of Advanced Industrial Science and Technology (AIST), and the Engineering Advancement Association of Japan (ENAA) were selected to make up of the Research Consortium for Methane Hydrate Resources in Japan. These three organizations consigned and subcontracted work to approximately 30 industries, universities and research institutes, which conducted research and development work by collating knowledge from almost 300 researchers.

The R&D Program was carried out by three groups, and the Secretariat for Research Consortium for Methane Hydrate Resources in Japan was set up to assist those groups in carrying out their activities. Each group took charge as follows.

(1) The Research Group for Resources Assessment (JOGMEC in charge)
- Researches for exploration techniques of methane hydrate-bearing layers
- Developments and evaluations of technologies for resource assessment
- Researches for technologies of well drilling / completions / production.

(2) The Research Group for Production Method and Modeling (AIST in charge)
- Investigation of fundamental properties of methane hydrate-bearing layers
- Developments of production simulator and various recovery technologies.

(3) The Research Group for Environment Impact (ENAA in charge)
- Investigation of offshore environment
- Environment impact assessment

(4) The Secretariat for Research Consortium for Methane Hydrate Resources in Japan (JOGMEC in charge)
- Administering, budgeting and contracting projects of the Research Consortium for Methane Hydrate Resources in Japan
- Management of public affairs, promotion of achievements, and other activities

Working groups and taskforces were set up as sites for information sharing and collaborative work among researchers of these groups in order to promote the research and facilitate operations (refer to

Figure 3-2).

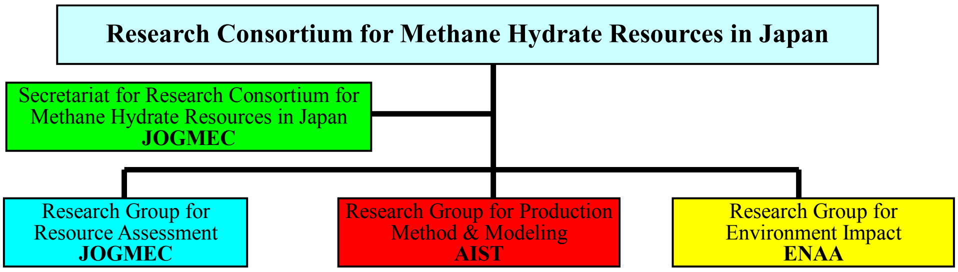


Figure 3-2 Implementation structure of the Research Consortium for Methane Hydrate Resources in Japan

4. Principal Events in Phase 1

- July 19, 2001: "Japan's Methane Hydrate R&D Program" was announced.
- December 2001 to March 2002: The First Onshore Methane Hydrate Production Test was carried out
- March 20, 2002: The Research Consortium for Methane Hydrate Resources in Japan was founded.
- April 3, 2002: The first Advisory Committee for National Methane Hydrate R&D Program
- FY 2001: METI "Tokai-oki to Kumano-nada" (2D) seismic surveys
- (Reference) FY 2001: METI "Sado-oki Nansei" (2D) seismic surveys
- FY 2002: METI "Tokai-oki to Kumano-nada" (3D) seismic surveys
- December 2003: Mallik International Symposium in Makuhari
- January to May 2004: METI Exploratory Test Wells "Tokai-oki to Kumano-nada"
- April to May 2005: The Advisory Committee for Promotion and Evaluation of National Methane Hydrate R&D Program (the first and the second meetings)
- July 2005: The Evaluation Subcommittee of Industrial Technology Sectional Committee of Industrial Structure Council
- January to March 2006: Council for Science and Technology Policy Expert Panel on Evaluation
- July 2006: The Advisory Committee for Promotion and Evaluation of National Methane Hydrate R&D Program (the third meeting)
- December 2006 to April 2007: The first winter test for the Second Onshore Methane Hydrate Production Test
- January to April 2008: The second winter test for the Second Onshore Methane Hydrate Production Test

5. Status of Achievement of R&D Program Goals

The implementation plan of Phase 1, which was instituted in line with the R&D Program., was deliberated and investigated in the first Advisory Committee for National Methane Hydrate R&D Program, and the plan has almost been accomplished except for the delay related to the Onshore Production Test. The status of the achievements of the goals of the objectives 1, 2, 3, and 6 in R&D Program chapter II are summarized below, which may comprehensively indicate the accomplishments of Phase 1.

Regarding the achievements of the Onshore Production Test and the advances of simulators, they are of such importance that we describe them in detail in the articles of “6. Achievements of the Onshore Gas Hydrate Production Test,” and “7. The Production Simulator,” respectively.

Emphatic points of the achievements of the other items are summed up in the article of “8. Predominant Results of Items Above.”

5.1 Objective 1: Clarification of MH occurrences and characteristics offshore Japan

As the investigation of BSR (Bottom Simulating Reflector) distributions around Japan (Figure 5-1) predominantly conducted by the former JNOC (Japan National Oil Corporation) has been taken over, geophysical explorations in southwest offshore of the Sado Island as well as geophysical explorations and MITI exploratory test well in the eastern Nankai Trough area have been carried out after the R&D Program commenced. Thirty two (32) wells were drilled in the METI Exploratory Test Wells “Tokai-oki to Kumano-nada,” and various new analysis techniques have been established by comparing the data of LWD (Logging While Drilling), wireline logging and core recovery with the 2D/ 3D seismic data. We are now able to interpret existing seismic survey data to a high level of accuracy.

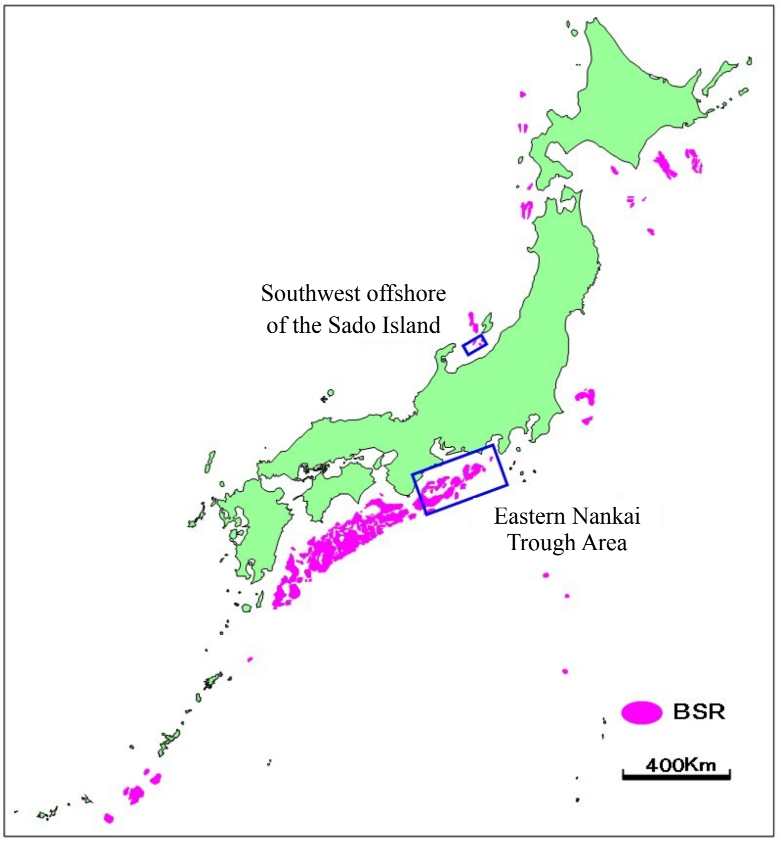


Figure 5-1 BSR distributions in the surrounding offshore areas around Japan

While the BSR has usually been used as an indicator of the existence of methane hydrate, the new technique was obtained to clarify what the BSR indicates and to quantitatively recognize the methane hydrate-bearing layers according to comprehensive examinations of the geophysical explorations and the MITI exploratory test well in the eastern Nankai Trough area.

(1) Since the BSR occurs at the interface between the base of the methane hydrate stability zone and the free gas-bearing water layers beneath, the BSR is not observed when methane hydrates exist only in shallower depths away from the BSR.

(2) The BSR is sometimes recognized simply due to the seismic phase change and so on instead of the identification of distinct seismic reflector.

(3) The BSR denotes the existence of methane hydrate qualitatively, and as an indicator is insufficient for showing the amount of resources.

(4) The methodology was established to delineate methane hydrate concentrated zones and the amount of gas trapped was evaluated.

The existence of methane hydrate became clear in the METI Exploratory Test Wells “Tokai-oki to Kumano-nada” and was found to be distributed in sand sediments of turbidite sand and mud alternation layers (refer to the picture in Figure 2-3). Figure 5-2 shows an example of logging data denoting methane hydrate concentrated zones in turbidite sand and mud alternation layers. Those methane hydrate concentrated zones are recognized as being high-resistivity and high-velocity zones on the logging data.

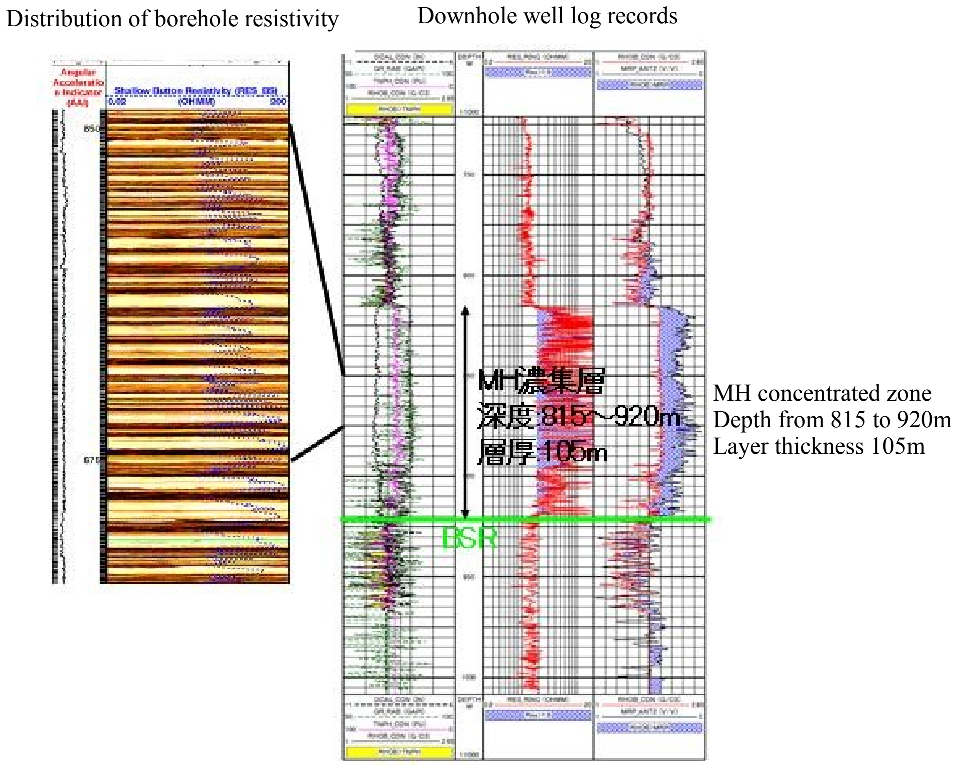


Figure 5-2 Example of the downhole well log data denoting turbidite sand and mud alteration layers

The geological characteristics of turbidite sand and mud alternation layers in the eastern Nankai Trough area are summarized in Figure5-3.

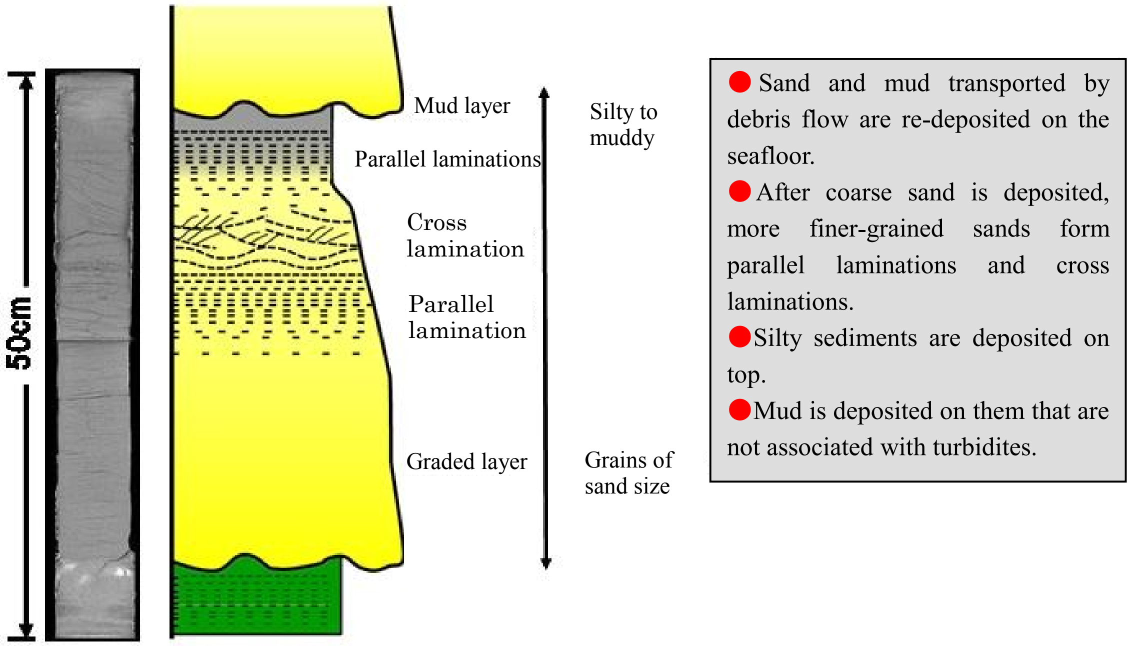


Figure5-3 Geological characteristics of turbidite sand and mud alternation layers

When coarse sediments deposited at shallow depths are mixed with circumjacent fluids, fluidized and transported into the deep sea by earthquakes, storm winds and tsunami once every few decades or hundred years, these sediments form into so-called submarine fans. They form alternating beds of sand and mud offshore where only fine-grained mud can be deposited, and are called turbidite layers. These are recognized as the shapes of a channel and a lobe in seismic data. In these layers, methane hydrate is understood to concentrate in the methane hydrate stability zone indicated by BSRs (Figure 5-4).

Since sedimentary formations where methane hydrate is concentrated continuously on a broad scale are considered to be promising, they are defined as methane hydrate concentrated zones and evaluated differently from other methane hydrate-bearing layers.

We then examined all the data obtained from the METI Exploratory Test Wells "Tokai-oki to Kumano-nada," and fixed criteria of the high resistivity layer to be greater than 3Ω・m in wells and thicker than 10m in net thickness as a threshold level to distinguish the methane hydrate concentrated zones from other zones. Based on this criterion, we checked several properties shown on the seismic data at the locations with well controls, and confirmed the method to be used by picking the methane hydrate concentrated zones out from the reflection seismic data by using the following four indices:

A) Existence of BSRs

B) Distributions of turbidite sand and mud alternation layers such as channels and lobes above BSRs

C) High amplitude reflector

D) High velocity anomaly

In addition, 16 methane hydrate concentrated zones have been identified in the eastern Nankai Trough area using this method. The normal characteristics of methane hydrate concentrated zones are estimated, and values of net/ gross ratio 0.37, porosity 0.44 and methane hydrate saturation 0.51 are obtained.

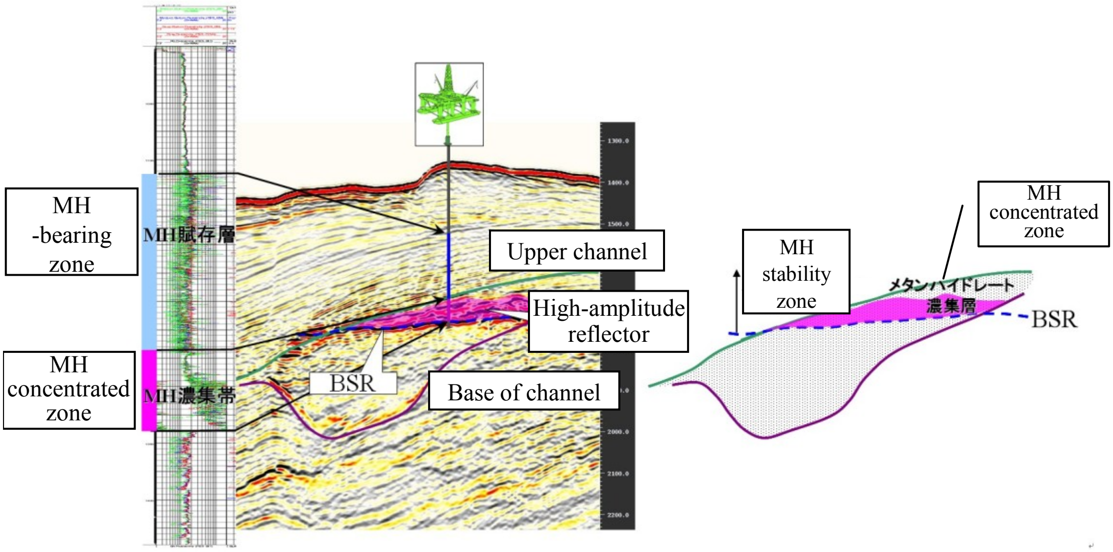


Figure 5-4 Example of methane hydrate concentrated zones
(the methane hydrate concentrated zone β)

Since the concept of "Methane Hydrate Concentrated Zone" and the method for its evaluation were confirmed, the following have become feasible.

(1) Probabilistic calculations of original gas in places became feasible (refer to the article 5.2).

(2) Abstractions of the potential areas with methane hydrate concentrated zones became feasible by applying the newly established analytical technique of geophysical exploration to other areas.

The physical properties of turbidite sand and mud alternation layers as reservoirs recognized in the METI Exploratory Test Wells "Tokai-oki to Kumano-nada" have been pursued by the analyses of recovered core samples and the project standard samples simulating methane hydrate-bearing layers. For this purpose, the technique of making the artificial methane hydrate sediment core that simulate the core samples recovered from the METI/MITI Exploratory Test Wells has been developed, and the basic technique of measuring the physical properties of sediments at the in-situ conditions has been improved (refer to the article 8.2).

The physical properties of those turbidite sand and mud alternation layers as reservoirs may serve as a basis of data input to the production simulators for evaluating the production volumes and figuring out the economic potential. Prevailing values of the physical properties are shown below.

A) Thermal property

Thermal conductivity;

Sandy cores: 1.56W/m・K, Muddy cores: 1.15W/m・K

Cores in the vicinity of the interface between alternating beds of sand and mud:

1.7 - 2.3W/m・K

Specific heat (15˚C)；

Sand grain of sandy cores: 0.82J/g・K

Muddy parts: 0.77J/g・K

Methane hydrate-bearing layers (porosity 40%, methane hydrate saturation 60%): 1.26J/g・K

Massive methane hydrates: 1.91J/g・K

B) Permeability characteristics

Absolute permeability of sandy cores after methane hydrate dissociated: a few millidarcies - a couple of 100 millidarcies (anisotropic nature possibly)

Absolute permeability of muddy sediments: a few μ darcies - a couple of 100μ darcies

C) Characteristics of Elastic Wave

Core samples recovered from the METI/MITI Exploratory Test Wells with 30% of methane hydrate saturation: P wave 2,000m/s, S wave 800m/s

Increasing rate per 10% of methane hydrate saturation: P wave 140m/s, S wave 110m/s

D) Resistivity characteristics

At around 3Ω・m for core samples with a few percent of methane hydrate saturation

E) Grain size (sandy sediments cores)

Relatively large sand grains with 100μm - 300μm in grain diameter, 200μm on average grain size at the base of sandy sediments, smaller than 100μm on average grain size at the top of sandy sediments. Alternations may contain silts more than 10% near the boundary with muddy sediments.

F) Bulk density

Sandy cores: 1.6 - 1.9, Muddy cores: 1.9 - 2.0

G) Porosity

Sandy cores: 40% - 45%, Muddy cores: 36% - 40%

H) Methane hydrate saturation

Cores of sandy sediments: 40% - 50% (those values are considered much larger at the in-situ conditions due to hydrate dissociation processes at the time of measurements)

Muddy cores: those scarcely contain methane hydrate.

Cores in the vicinity of the interface between alternating beds of sand and mud: 1% - 3%

I) Dissociation gas

Sandy cores: methane, ethane is detected to 600ppm - 2,800ppm in the cores from some areas

Muddy cores: around 1ml/g of CO_2 has been detected.

J) Strength of methane hydrate-bearing layers

Strength of the alternating beds of sand and mud with 60% of methane hydrate saturation around the depth of 100m below the seafloor, which is estimated from the measured values of sandy cores: 7MPa - 8MPa. Studies on strength of the interface between alternating beds of sand and mud are also in progress.

K) Influence of methane hydrate dissociation

Strength of alternations decreases to about half the primary strength due to dissociation of methane hydrate accompanied by the advancement of consolidation and a decrease in absolute permeability.

L) Capillary pressure measurement

Muddy cores: Pressure at the beginning of injection is 0.14MPa. Pressure at 20% of injection is 1MPa. They have sufficient seal capacity of gas.

5.2 Objective 2: Assessment of methane gas amounts in promising methane hydrate bearing offshore areas

Under the study of the preceding section 5.1 (the Objective 1), we selected the eastern Nankai Trough area (refer to Figure 5-1) as being a promising methane hydrate bearing area, and calculated the original methane gas in place in methane hydrate-bearing layers in sea areas. The calculation method is based on the volumetric method taking the range of uncertainty of each parameter into account, and evaluations by the stochastic method were adopted. We abstracted the methane hydrate concentrated zones and the spatial distributions of methane hydrate-bearing layers at the same offshore area shown in Figure 5-4, and calculated the amount of original gas in existence. An equation was introduced that was modified and was applicable to methane hydrate from the equation of volumetric method adapted to the conventional resources.

The methane hydrate concentrated zones:

$$\text{The original methane gas in place} = GRV \times N/G \times \varphi \times S_{MH} \times VR \times CO$$

Methane hydrate-bearing layers (other than the methane hydrate concentrated zones):

$$\text{The original methane gas in place} = \text{Area} \times \text{Net} \times \varphi \times S_{MH} \times \text{VR} \times \text{CO}$$

Parameters used above are listed in Table 5-1.

Table 5-1 Parameters used in calculating resource volume of methane hydrate

Parameters	unit	Assumed probability distribution
GRV (gross rock volume)	million m^3	Log normal distribution
N/G (net/gross ratio, ratio of sandy layer in alternating beds of sand and mud)	fraction	Log normal distribution
φ (porosity)	fraction	Normal distribution
S_{MH} (methane hydrate saturation)	fraction	Normal distribution
VR (volume ratio)	fixed number	Uniform distribution (172@0˚C・atmospheric pressure)
CO (cage occupancy)	fraction	Triangular distribution (0.95 on average obtained from natural samples)
Area (area of distribution)	km^3	Log normal distribution
Net (net thickness of sandy sediment)	m	Log normal distribution

The original methane gas in place in the methane hydrate-bearing layers in the eastern Nankai Trough area is calculated using the above methods, and their results are summarized in Table 5-2. Calculations are carried out in each field containing a distribution of methane hydrate, and the total amounts are simply a sum. The original methane gas in place is a volume of methane at standard conditions (0˚C, atmospheric pressure), which are assumed to derive from the dissociation of methane hydrates into water and methane in subsurface formations. Some of these gases are produced to the surface, and the rest remains in the subsurface formations. The ratio of gas produced at the surface has not yet been determined, however it should become clear from an analysis of the results of the production test and a study of the production simulation.

Table 5-2 Calculation results of the original methane gas in place in the methane hydrate-bearing layers in the eastern Nankai Trough area

	Total volume of methane initially considered to exist (100million m^3)		
Grouping	P90	Pmean	P10
Methane hydrate concentrated zones	1,769	5,739	11,148
Methane hydrate-bearing layers	1,067	5,676	12,208
Total	2,836	11,415	23,356

P90: Estimated occupied volume greater than this value, the probability of which exceeds 90%
Pmean: The mean value
P10: Estimated occupied volume larger than this value of which probability exceeds 10%

5.3 Objective 3: Selection of methane hydrate resource fields from promising methane hydrate bearing offshore areas and deliberation of economic potential

This objective is divided into two aims such as selecting the methane hydrate resource fields and deliberating economic potential. Evaluations of the achievements of both of the above are conducted with scrupulous coordination, and are described separately for practical convenience.

1) Selection of the Methane Hydrate Resource Fields

The locations with well data of the METI/MITI Exploratory Test Wells extracted from methane hydrate concentrated zones at the 16 zones defined in section 5.1 were targeted for investigation of 41 items, and three methane hydrate concentrated zones (α, β, and γ) were adopted as the candidate areas for offshore production tests. Detailed geological models were constructed at the two concentrated zones of α and β. Based on these models, reservoir models were built in a $1km^2$ vicinity around the well, and production simulations were carried out. (Regarding the production simulation, refer to section “7. The Production Simulator”)

The 41 items used for the adoption are listed below.

- Original gas in place
- Geological items: volume, area, thickness of layer, stratigraphy, reservoir type, sedimentation pattern
- Site situations: water depth, distance from the shore
- Reservoir characteristics: reservoir thickness, sand/mud ratio, reservoir continuity, vertical permeability in reservoirs, degree of consolidation of sands and mud, depth of reservoirs, reservoir temperature, dip and strike of the reservoirs, existence of water layers in the reservoirs, permeability of the layer above the reservoir, existence of methane hydrate in the layer above the reservoir, existence of fault and fracture, permeability of the layer beneath the reservoir
- Production relevance: predictions of productivities, predictions of production damages
- Seafloor environments: inclinations of the seafloor, properties of sediments on the seafloor, existence of drilling troubles, circumjacent seafloor topography
- Offshore environments: meteorological phenomena, hydrographic phenomena, ocean currents and tidal currents, background concentrations of dissolved methane in sea water, methane fluxes from the sediments, methane fluxes presumed by SMI depths, marine mammals, marine reptilians, ocean ranging fishes, benthonic living organisms
- Others: fishing activities, submarine cables, sham battle fields

(Remarks: SMI=Sulfate Methane Interface, which is a sulfate-methane boundary and one of the markers indicating methane fluxes adjacent to the sea floor.)

Characteristics of the ten out of the 41 items investigated in the three selected zones of the methane hydrate resource field are summarized in Table 5-3.

Table 5-3 Three candidates of the methane hydrate concentrated zones in the methane hydrate resource fields

Items	**Methane Hydrate Concentrated Zone α**	**Methane Hydrate Concentrated Zone β**	**Methane Hydrate Concentrated Zone γ**
Original gas in place: Pmean (100million m^3)	591	87	111
Area (km^2)	35.5	12.3	23.7
Total average thickness (m)	62.3	39.6	37.8
Water depth (m)	675 - 878	857 - 1405	855 - 1,035
Distance from shore (km)	40 - 50	70 - 80	40 - 50
Reservoir types	turbidite sand and mud alternation layers	turbidite sand and mud alternation layers	turbidite sand and mud alternation layers
Depth of reservoirs (m)	α-1 Well: 815 - 919 α-2 Well: 922 - 953	β-1 Well: 1,295 - 1,339	γ-1 Well: 1,167 - 1,193
Formation temperature (˚C)	α-1Well Site 8.6 - 10.3	β-1 Well Site 12.7 - 14.3	γ-1 Well Site 12.5 - 13.2
Inclination of seafloor	Less than 2 degrees around the α-1 and α-2 wells.	Sometimes exceeds 10 degrees at some sites as the circumjacent seafloor topography is convoluted around the β-1 well. The general inclination is approximately 3 degrees on average. Some areas of the seafloors are virtually flat.	Less than 2 degrees around the γ-1 well.
Circumjacent seafloor topography	The topography is a gentle slope around the α-1 and α-2 wells. A steep escarpment begins at the site 5km east of the well, and continues to the depression.	The seafloor topography is convoluted around the β-1 well and has a rise in the south. The trace of submarine landslide is recognized at the site 4km northwest of the well.	The topography is a gentle slope around the γ-1 well. A steep escarpment begins at the site 4km from the well continuing to the submarine canyon.

2) Deliberation of Economic Potential

The aims of the economic potential deliberations are to develop an economic evaluation program that is suitable for the exploitation of methane hydrate, to create a vision for the feasibility of methane hydrate exploitation, to compare the estimated production costs expected from the present stage of research to those of conventional resources, to discover issues related to developing technologies, and so on.

We deliberated on economic potential based on the production behaviors simulated for the methane hydrate concentrated zone α that were selected in the preceding section. We used the MH-ECONOMICS Basic Model economic evaluation program that has been developed and found suitable for the exploitation of methane hydrate.

The R&D Program was configured with business operations to commence in 2016, production to commence in 2021, a production period of 15 years, and a production leadtime of each well for eight years. Also, according to inquiries about fluctuating gas prices and other factors, the price of gas in 2004 was configured to be 23.8JPY/m^3, the rate of inflation was 2.56% as an annual percentage rate, and the rate of increase in gas prices was 3.88% as an annual percentage rate.

Regarding the development system, production facilities will be put into place on the seafloor. Gases produced will be collected on the offshore platform and transported via pipeline to the destination for consumption. More specifically, a number of wells will be connected to the manifold set up on the seafloor, and the gases produced and water on the manifold will be separated by the separator. After being separated, the produced waters will be injected into the subsurface formations. After the gases produced are pressurized to a few MPa and collected on the offshore platform, they will be re-pressurized and delivered via pipeline to the destination for consumption.

Prevailing assumptions used for the deliberation of economic potential at this time are as follows.

(1) The geology is assumed to be uniform horizontally. The data of one of the wells drilled in this region have been adopted.

(2) Long-term production damage is estimated to be within the scope of the assumption. It is necessary for this to be substantiated by production and other tests.

(3) It is assumed that the volume of production will be fulfilled. The calculation by the production simulator has been applied.

(4) It is assumed that the equipment, technologies and other factors will be implemented. A study of unproved instruments and technologies will be necessary.

Since economic evaluation has been carried out for the six developing methods to the methane hydrate concentrated zone α, the flow chart and the evaluation results of the fundamental development method α-1, which is used as a case to exploit the circumference of the well α-1, are summarized in Figure 5-5.

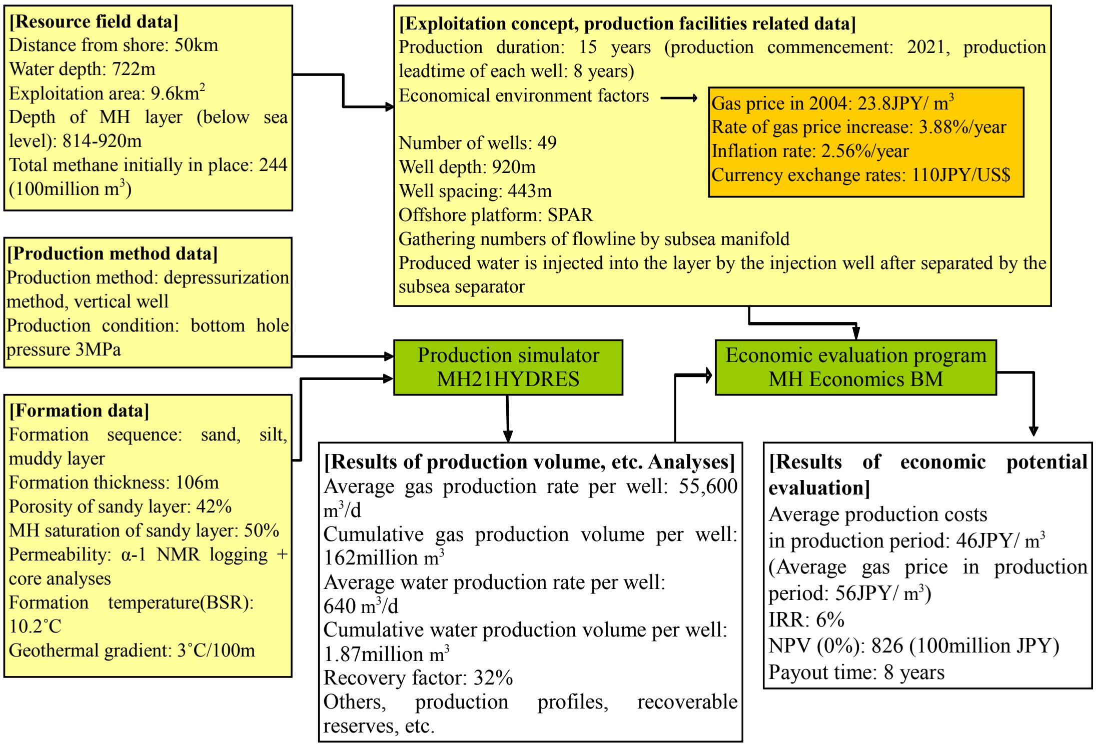


Figure 5-5 Flow chart of deliberating economic potential and evaluation results for the methane hydrate concentrated zone α-1

A trial calculation has been carried out for the production costs withdrawn from the methane hydrate-bearing layers assuming the following three patterns.

(1) A case postulating present construction costs: 92JPY/m^3

(the base price was set at that of 2004, and is assumed to have temporarily tripled)

(2) All the assumed conditions come into effect: 46JPY/m^3

(the base price of 2004)

(3) Production volume lower (by a quarter) than expected: 174JPY/m^3

Technology development issues have been investigated with sensitivity analysis of the economic potential. The approaches to an increase in the gas production rate, an improvement in the recovery factor, a reduction in the water production rate, a reduction in the sanding rate and so on from the viewpoint of technology development, a cost reduction analysis of the subsea system, and a cost reduction analysis of the building of facilities from viewpoint of development system were analyzed as being highly effective with regard to advancing the economic potential.

5.4 Objective 6: Establishment of a development system complying with environment

The basic concepts for objective 6 are described in the section "V. Contents of Technology Developments, 5. Environment" of the R&D Program as follows.

"Regarding the exploitation of methane hydrate, it is necessary to take the influence to the margin of safety of the exploitation operation itself, the impact to marine ecosystems, and the effects of leaked methane gas into account.

The causes of the above are considered to be the effluence of development-related low-temperature fluid coming to the sea surface, the critical damage of cement and the casing in itself due to consolidation of the formations around the well associated with the production, the decreased functional status of the formation seal capacity above the methane hydrate-bearing layer due to the deformation, subsidence and other reasons related to the seafloor, the collapse of the methane hydrate-bearing layer itself, and so on.

As these phenomena are closely related to the in-situ characteristics of the formations as well as the exploitation and production methods, it should be necessary to gain a thorough understanding of the properties of the methane hydrate-bearing layers and the nature of circumference formations and to carry out an analysis after due consideration of their characteristics is made. Furthermore, it is crucial to investigate the interannual environmental change of the topography and ecological systems of the seafloor, and so on in the model fields."

In Phase 1, surveys of offshore environment centered around the eastern Nankai Trough have been carried out on two occasions - before and after the METI Exploratory Test Wells "Tokai-oki to Kumano-nada," and interannual observations have been conducted for some items. In the METI Exploratory Wells mentioned above, entire interval core recoveries were attempted in two sites to retrieve all the geological core samples from the seafloor to the layer below the methane hydrate-bearing layer. The core recovery ratio was low due to water depths ranging from 700 to 1,000m, most of which were clayey samples at shallower depths.

The research status relating to the developments of prediction techniques of the sediment deformation, the offshore environment surveillances and "the macro risk assessments of environmental impacts" directed by the Council for Science and Technology Policy Expert Panel on Evaluation (March 2006) are summarized in this section.

1) Analyses of the Core Samples from the METI/MITI Exploratory Test Wells and Developments of Prediction Techniques of the Sediment Deformation

The corings were carried out to recover the geological core samples from the seafloor to a depth of approximately 250m below the BSR in the two wells of the METI Exploratory Test Wells "Tokai-oki to Kumano-nada." The water depth was approximately 1,000m, and the core recovery ratio of sandy samples was low. The physical and mechanical properties of the seafloor were estimated by index tests, consolidation tests and triaxial compression tests using those core samples recovered from the METI Exploratory Test Well.

Measurements of density, consistency, grain size distribution and clay minerals were taken by index tests, and subsequently, the fundamental physical properties were understood. Those samples should be classified as low liquidity clays from an engineering viewpoint.

The consolidation yielding stress was obtained under one-dimensional compression to the consolidation pressure up to 5MPa. It was confirmed that those sediments were in a state of overconsolidation near the seafloor, but that they were in a normally consolidation state below a depth of approximately 100m.

In the triaxial compression tests, the undrained shear tests with controlling strain rate were carried out after reproducing in-situ stress history by K_0 consolidation to the consolidation yielding stress obtained from the consolidation tests and K_0 unloading to the in-situ overburden pressure so as to minimize the influences of sample disturbance on the test results.

The constitutive equation of the ground was built to express to an adequate level of accuracy the mechanical properties of the seabed ground on the basis of the test results noted above.

The simulations and the three dimensional analyses by the finite element method were undertaken for the results of triaxial compression tests, and the microscopical behaviors in the specimens such as the non-uniformities in deformations and strains as well as the macroscopic behaviors of the specimens were also investigated. Figure 5-6 shows an example of the distribution of volumetric strain on the surface of specimen. It can be seen that the volumetric strain in the compression direction in the upper and bottom ends of the specimen as the volumetric strain in the expansion direction gradually concentrates at the center of the specimen with the axial strain increasing. As the analytical results and experimental results show identical tendencies, it is confirmed that the analytical results express well the experimental results.

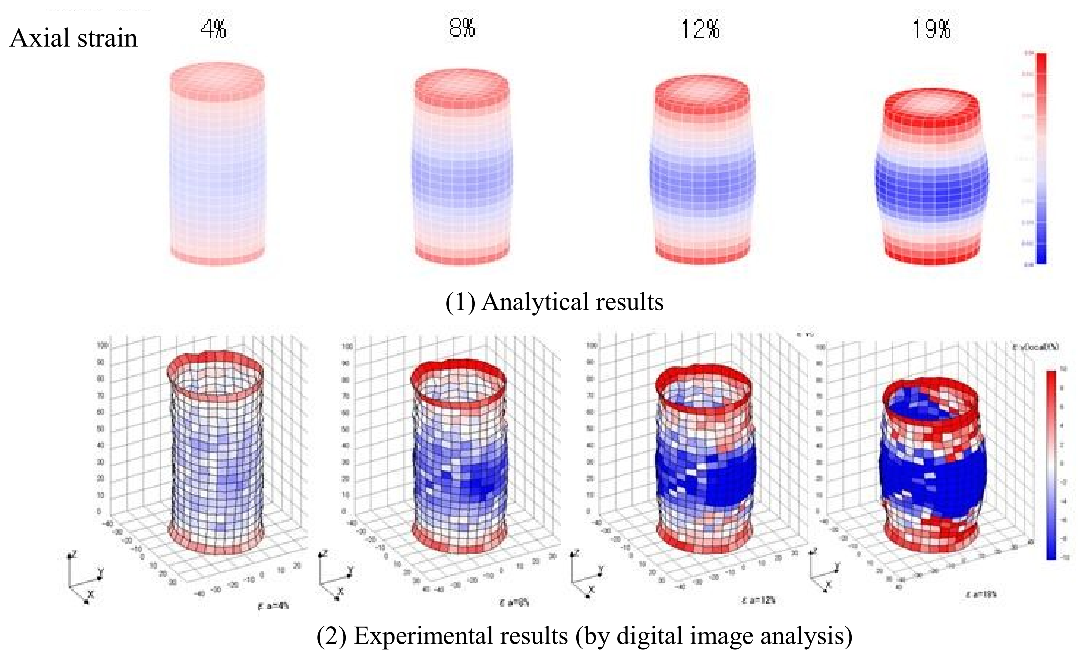


Figure 5-6 A result of the numerical analyses for the tri-axial compression tests of the core samples obtained from the METI/MITI Exploratory Test Wells (the distribution of volumetric strain)

From the results investigated above, it is confirmed that the constructed constitutive equation can express well the experimental results.

The prediction program for stratum deformation was developed by taking in account the constructed constitutive equation of the seabed ground. After the modules of the core system which controls the whole program, stratum subsystem, analysis subsystem and load subsystem were created, the validation between subsystems and whole system including including core system were carried out.

It became possible to predict the deformation of the whole seabed ground with the development program noted above by taking in the displacement data of production stratum calculated by the simulator developed in the Research Group for Production Method and Modeling. By indirect combination, the preliminary analyses for the offshore production test was carried out, and the fundamental data contributing to the seafloor displacement monitoring and measuring plan at the time of offshore production tests were documented based on the above analytical results.

2) Acquisition of the Baseline Data in the Offshore Environments and Development of the Prediction Technique for Biological Influences

Offshore environment surveys have been conducted in the Tokai-oki to Kumano-nada to evaluate the overall offshore environment where drillings of METI Exploratory Wells is being prepared. Offshore environment surveillance in a broad area of the Nankai Trough was carried out from FY 2003 to FY 2005, and the interannual characteristics of the water mass structure, the environmental water and sediment quality and the biological environment were obtained in the three areas of Tokai-oki, the Daini-Atsumi Knoll offshore, and Kumano-nada. In addition, offshore environment surveillance was also conducted in various seasons in FY 2006 and FY 2007 at the same location around the area where the METI/MITI Exploratory Test Wells were drilled, and the seasonal differences of the above items were obtained. According to this baseline data, the characteristics of offshore environments in the surrounding area of the eastern Nankai Trough and that where the METI/MITI Exploratory Test Wells were drilled were analyzed, and the following points were clarified.

The relevant area is affected by the movements of the Kuroshio axis, and offshore structure is composed of the four masses of water such as coastal water, the water of the Kuroshio region, the water of subtropical zones and Pacific deep water.

The current pattern has a fifteen-day cycle near the seafloor in the Tokai-oki region. The current field from the intermediate to the bottom layers near the Daini-Atsumi Knoll is complex, because it may possibly be influenced by the complex topography of the seafloor. The current pattern in the Kumano-nada region has a 31-day cycle near the seafloor, which is different in flow patterns from that in the Tokai-oki region. Results also indicate the possibility it has been affected by the meandering state of Kuroshio

The maximum concentrations of dissolved methane reache approximately 10nmol/kg. This methane is assumed to be supplied from the seafloor anywhere in this offshore area.

- The vertical distribution profile of dissolved methane in the water column has a trend to increase the concentration such as 3 - 4nmol/kg near the seafloor and the intermediate layer in these three areas. In particular, it exceeds 7nmol/kg near the seafloor in the Kumano-nada. The cause of increasing dissolved methane near the seafloor and the intermediate layer of water column is considered to arise from the existence of cold seep zones in the Tokai-oki and near the Daini-Atsumi Knoll regions, and from mud volcanoes in the Kumano-nada region.
- The leaching rate of methane from the seafloor was 3.1 - 64.6 (average 27.7) nmol/m^2/h in the Tokai-oki, 6.1 - 31.9 (average 19.4) nmol/m^2/h near the Daini-Atsumi Knoll, and 6.5 - 173.6 (average 64.9) nmol/m^2/h in the Kumano-nada regions. A higher leaching rate of methane was observed in the Kumano-nada region. It is confirmed that the leaching rate is higher in case that the volume of organic matter in sea bottom sediments in the offshore area is a lot.

- The grain size distribution of surfical sediment is significantly different among the three offshore areas. In the Tokai-oki region, sand and sand/mud are the main components, and the median of grain size is 94 - 200 μm. Near the Daini-Atsumi Knoll region, sand and mud are the main components, and the median of grain size is 13 - 94 μm, which is a little finer sediment compared to that of the Tokai-oki region. Meanwhile, in the Kumano-nada region, silt and clayey silt are the main components, and the median of grain size is 11 μm, which are the finest sediments among these three ocean regions.
- The major plankton groups living near the seafloor were the copepoda and amphipoda. In addition, large differences in species and biomass are not observed between in the Tokai-oki and the Daini-Atsumi Knoll regions.
- Regarding the biomass of the benthic organisms that have habitats in surfical sediment, the macrobenthos is the largest and lives in an area from the sediment surface to 5cm below the surface in the Tokai-oki region. The bacteria is the largest and lives in an area from the sediment surface to 25cm below the surface near the Daini-Atsumi Knoll region. This depth is deeper than that observed in the Tokai-oki region. The biomass in the Kumano-nada region is the highest in the three offshore regions, more than 90% of which is occupied by the bacteria.

On the basis of the results noted above, we considered the kind of index we should use to assess the environmental variation during the offshore production test in the relevant offshore areas in the future.

As the prediction technique for biological influences, we have created a new model that added the function of reproducing the behavior of frothy methane seeped from seafloor to sea water into the diffusion model of oil and natural gas in water columns called CDOG (Comprehensive Deepwater Oil and Gas Blowout Model). Its behaivor is that the change of bubble size against temperature and pressure change, the formation of hydrate film coating bubble surfaces and so on. We have also developed a prediction model for the diffusive areas of water from dissociation of methane hydrate in sea water.

We considered the advisability of the direct effect and the extent of the impact for aquatic organisms incorporated the results for diffusions of methane and discharged dissociated water using our models into the acute toxicity value, that is median lethal concentration and median effective concentration, of methane for aquatic organisms and the resistant data of aquatic organisms for the discriminative low salinity of discharged dissociated waters.

Figure 5-7 (left hand figure) showed an example of calculation for the continuous leakage of methane gas from the seafloor for six hours with the rate of $0.1Nm^3/sec$ under the condition of water temperature, salinity and current velocity in October near the Daini-Atsumi Knoll. The methane gas came up rapidly, diluted and diffused with having dissolved in sea water. The hydrate formed methane gas did not reach the sea surface since it dissolved in sea water after disaggregating to gas up to the depth 100 - 200m below the sea surface. As a result of investigating the extent of methane impact on living organisms from the median lethal concentration for fish and the median effective concentration for shellfish, the organism group living tens of meters from the center of the methane plume is estimated to be directly affected.

We estimated the diffusion of water from dissociation of methane hydrate in the case of having discharged from the sea surface, the intermediate layer and the seafloor. In the case of discharge from the intermediate layer, it was found that the water from dissociation of methane hydrate rises to the sea surface and spreads due to the lower density there than in surrounding sea water, and that it diffuses horizontally by the flow of each layer. This is because the water from dissociation of methane hydrate is supposed to be fresh water.

In discharging from the seafloor (Figure 5-7 (right hand figure)), the water from dissociation of methane hydrate is not considered to have much of a direct effect on the benthic living organisms as the discharged water will never emanate from the seafloor. In discharging from the sea surface, the influence on the planktons and so on in the surrounding areas is estimated to be small as the vertical extensity is around a few meters and the horizontal extensity is also around 10m. In other results of calculation with changing the volume of discharge, the discharged water diffuses relatively for a short time because of the effect of the surrounding ocean currents, and the domain of low salinity area is limited in the vicinity of discharge vents. It is presumable that the extent of impact of water from dissociation of methane hydrate on organisms living in the surrounding sea water is possibly within narrow limits near the discharge vents.

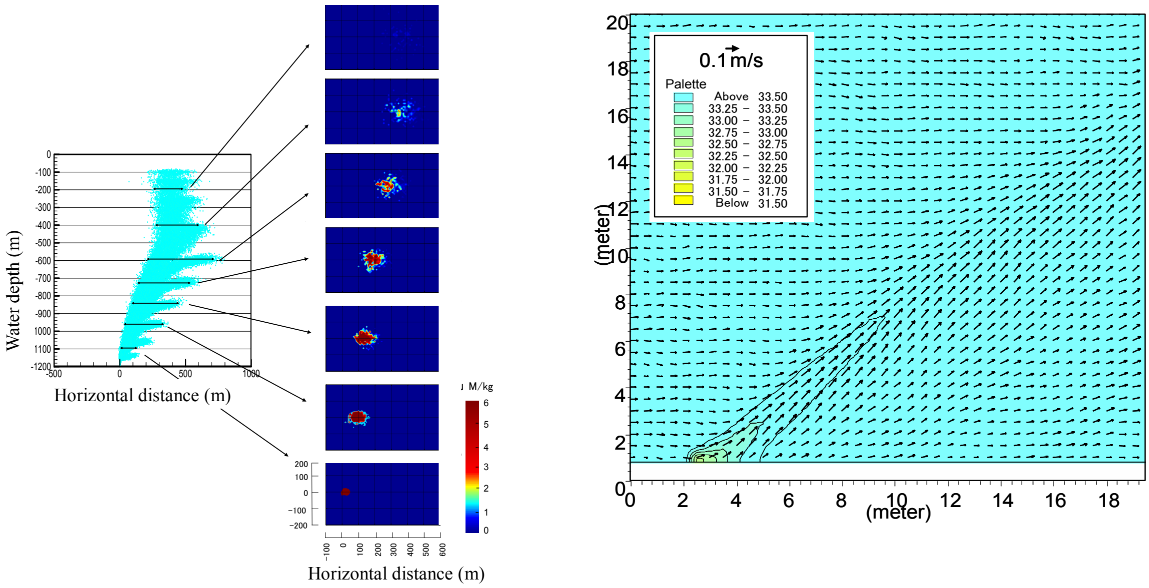


Figure 5-7 An example of calculation results for the prediction model
(left hand figure) An example of the calculation result for the prediction model of the behavior of leaked methane. The result of diffusion calculations in the case of methane that has leaked at 0.1Nm^3/s from the seafloor (after six hours)
(right hand figure) An example of the calculation result for the prediction model of the effects of water from dissociation of methane hydrate. The salinity distribution in the case of releasing discharged dissociated water from the seafloor at the rate of 0.001m^3/s (two hours after the release)

3) The Relationship between Methane Hydrates and the Global Environmental Risk

Based on the understanding in this report that "the macro risk assessments of environmental impacts" means the assessment of global environmental risks (such as global warming), we have carried out research on environmental risks which naturally occurs on a global scale, and human-induced environmental risks derived from exploitating methane hydrate.

(a) Environmental risks naturally occurring on a global scale

There is a hypothesis that methane could be discharged naturally from the subsurface methane hydrate-bearing layers into sea water and moreover into the air after the collapse of the subsurface methane hydrate-bearing layers sometimes arise spontaneously. Literature review has been carried out to investigate the hypothesis of the three conceivable effects (risks) on the global environment and those effects are summarized as follows.

(1) The collapse of methane hydrate-bearing layers due to global warming, which further accelerates warming.

(2) As the earth moves toward glacial stage, sea level would decrease and it would cause decrease of seafloor pressure and increase of sea water temperature. This may result in collapse of the methane hydrate-bearing layers and may cause large-scale landslides

(3) A significant amount of methane discharged from the collapsed methane hydrate-bearing layers will consume oxygen in ocean water, which may result in the death of the significant number of living marine organisms due to the ocean anoxic event.

Many researchers are now undertaking research into the three risks mentioned above. Although several theories have been proposed to ascertain whether these were caused by the collapse of methane hydrate-bearing layers or other causes, there are still no commonly-accepted notions at present.

According to the theory that proposes that these phenomena were caused by the collapse of methane hydrate-bearing layers, the collapse of methane hydrate-bearing layers itself is considered to be ascribed to climate change of the geological time-scale ranging from a few thousands to hundreds of thousand years. More specifically, those theory claims that the collapse of the methane hydrate-bearing layers would occur as a result of climate change such as increase of seafloor temperature or significant decrease of the sea level over a significantly long period of time.

As stated above, the current discussion over the risk of global warming on methane hydrate are mainly based on hypothesis that global-scale collapse of the methane hydrate-bearing layer occurs due to global climate change over the geological time-scale that is longer than a few thousands of years.

(b) The human-induced environmental risks derived from exploitating methane hydrate

The exploitation of methane hydrate assumed in the R&D program is to use depressurization method to dissociate and extract methane hydrate from the methane hydrate-bearing layers distributed below the seafloor in the eastern Nankai Trough area.

The pressure and temperature conditions of the methane hydrate-saturated sandy sediments, which were discovered by the MITI Exploratory Test Well "Nankai Trough" drilled in the eastern Nankai Trough area, is depicted as an example in Figure 2-1. As just described, offshore methane hydrates are distributed as solid substances in conditions in which temperature is approximately ten Degree Celsius and pressure is higher than 10MPa at 200m below the seafloor locating approximately 1,000m below the sea level. The exploitation of methane hydrate targets hydrate that is stably occupied as a solid state filling the pore spaces of sandy sediments. The exploitation of this type of methane hydrate requires human operation such as depressurization or increase of temperature through extraction well. If operations are terminated, the pressure and temperature may spontaneously return to their former state. Once pressure and temperature enter into the stable state, the dissociated methane gas will go back to the solid methane hydrate. This process will be deemed to be a safety mechanism during the exploitation and production process.

For this reason, the risks of methane gas leaking continuously out of the production system are considered to be rather low in the case some problems occur with production facilities and it has even been estimated that production of methane gas may stop during methane gas exploitating activities.

In addition, methane gas that is dissociated in the methane hydrate-bearing layers is transported from the subsurface formation to the offshore facilities through the well for production, and this process is similar to the exploitation of conventional natural gas. Therefore, for this process, the risk assessment of conventional natural gas exploitation could be applied.

(c) Further responses

As mentioned above, the anxiety over global warming accompanied by the collapse of methane hydrate-bearing layers as a natural phenomenon should be evaluated in terms of the geological time scale. In terms of human- induced environmental risks related to the production of methane gas from methane hydrate-bearing layers, we may be able to investigate those risks by looking at case examples involving the production of conventional natural gas. At the same time, as a number of researches on both issues are expected to be carried out, it would be necessary to collect information on research and developments etc. from academic meetings and other sources.

Although naturally-occurring global-scale environmental risks are not an issue directly associated with the R&D program, it is crucial to continuously collect and analyze information and to introduce beneficial information to the exploitation of methane hydrate, and to provide adequate information to the public.

6. Achievements of the Onshore Gas Hydrate Production Test

6.1 Results of the first Onshore Gas Hydrate Production Test

The first Onshore Gas Hydrate Production Test was carried out at the Mallik site in the Mackenzie Delta area, Northwest Territories, Canada, in 2002 as a collaborative research project among five countries (Japan, Canada, USA, India, and Germany) and seven research institutes (the former Japan National Oil Corporation- JOGMEC, Geological Survey of Canada, US Department of Energy, US Geological Survey, German GFZ, Indian Ministry of Petroleum and Natural Gas-India Oil and Gas Corporation, and Project of BP-ChevronTexaco Mackenzie Delta Joint Venture). At this site JNOC (Japan National Oil Corporation), the former JOGMEC, and the GSC (Geological Survey of Canada) conducted a survey in 1998, and discovered four or five pore filling type hydrate bearing sediments in sand layers at depths ranging from 890m to 1,100m below the permafrost zone continuing to a depth of 650m. From the production test carried out in 2002 in the Mallik 5L-38 well, we succeeded in producing about 470m^3 of gas within a five-day production period using the hot water circulation method, which is one of the thermal stimulation methods. In addition, the process of depressurization was monitored by the MDT (Modular Formation Dynamics Tester: registered mark of Schlumberger), and the emergence of gas was confirmed. Besides, data related to the formation permeability has been obtained through the pressure analyses and other information.

The JNOC took part in the production test, and analyses and studies of the acquired data have been conducted by the MH21.

6.2 Result of the Second Onshore Gas Hydrate Production Test

1) Purpose of the Second Onshore Gas Hydrate Production Test

The First Onshore Gas Hydrate Production Test carried out in 2002 was the first trial that had been carried out in the world up to that time that attempted to produce methane gas by dissociating the subsurface hydrate. However, future tasks remained to be carried out in terms of the issues of small production volumes and continuity. On the other hand, as the depressurization method became increasingly likely to be applied to the layers noted in the previous section, verification of the depressurization method in a field scale was desired with the intention of carrying out offshore production tests in future, and, moreover, the commercial viability of methane hydrate resources.

The purpose of the Second Onshore Gas Hydrate Production Test were to confirm that methane hydrates dissociate continuously over a long period of time in sediment using the depressurization method and to improve the accuracy of the production simulator by using obtained data there.

2) Preparatory Work

The Second Onshore Gas Hydrate Production Test was carried out twice in the winters of 2007 and 2008 by the JOGMEC and the Natural Resources Canada (NRCan) with the designated operator of the Aurora College, which is an educational institute in the Northwest Territories, Canada.

Since the area noted above is only accessible in the period when the rivers and the seas are frozen and ice roads can be constructed, all of the operations were limited to the winter season. Additionally, because this area is part of a vulnerable ecological system in the Arctic in which rare creatures are found, we took great care with regard to environmental conservation. Drilling wastes were brought back to the southern Canada for disposition, and the producted waters were injected into the aquifers below the hydrate-bearing layers. The Mallik 2L-38 well drilled in 1998 was utilized as the production well after having deepened, reamed, cased and cemented.

During the period from January through April 2007, the Mallik 2L-38 well was intervened after the ice road and the drill site were constructed, and physical property data of the hydrate-bearing layers was obtained from state of art physical logging tools at the same time. The delay of drilling as operations and other tasks due to the unusually cold winter made us abandon the plan of drilling observation well, but the Distributed Temperature Sensor (DTS, only down to the depth of 1,050m) and the electrodes for the streaming potential measurements were installed outside of the casing in the production well.

3) Production Test

Perforations were shot for the completion of the target layer from a depth of 1,081 to 1,093m that was the deepest layer in the hydrate-occurence zone of this area. Following that, the production test was carried out using the lower aquifer as the injection layer at a depth of approximately 1,300m in the same well.

During the limited operational period in the first winter of 2007, we put the electrical submersible pump below the perforation interval and carried out depressurizing by lowering the downhole water level by injecting the production water into the injection layer below. As a result, generation of gas was confirmed at a bottom-hole pressure of approximately 8MPa, which was higher than expected (the initial formation pressure was approximately 11.4MPa), and then production of 830m^3 of gas was observed during the depressurizing period for approximately 12.5 hours after being depressurized to 7.2MPa. However, as a large volume of sand flowed into the downhole much earlier than expected and the pump malfunctioned, we had no other choice but to stop the test 60 hours after commencement.

The well was abandoned temporarily in April 2007, and was spudded in again in January 2008.

According to the lesson learned the previous year, we placed a sand control device in the same interval as we did in the first winter, and the production water that was drawn to the surface was injected into the subsurface aquifer through another well after being measured. The bottom-hole pressure was finally depressurized to 4MPa, and we succeeded in producing a total of 13,000m^3 of gas at a production rate of 2,000 - 4,000m^3 per day for six days.

The temperatures and pressures were measured at the bottom-hole, the pump depth and the surface, and the samples of gas and water were obtained after measuring their production volumes on the surface.

The obtained samples and data are listed in Table 6-1.

We withdrew from the site after abandoning the well in April 2008.

4) Implication of the Onshore Gas Hydrate Production Test

This is an important step toward achieving the goal of utilizing methane hydrate as a resource since it was verified the gas can be produced continuously from the methane hydrate using the depressurization method. Based on this, the theoretical basis, simulator, and moreover the fundamental techniques for the depressurization were also considered to be verified, but future issues verifying the longer-term test and technologies able to be used in a offshore environment still remain to be carried out. As a matter of course, future progress in the research and developments is anticipated.

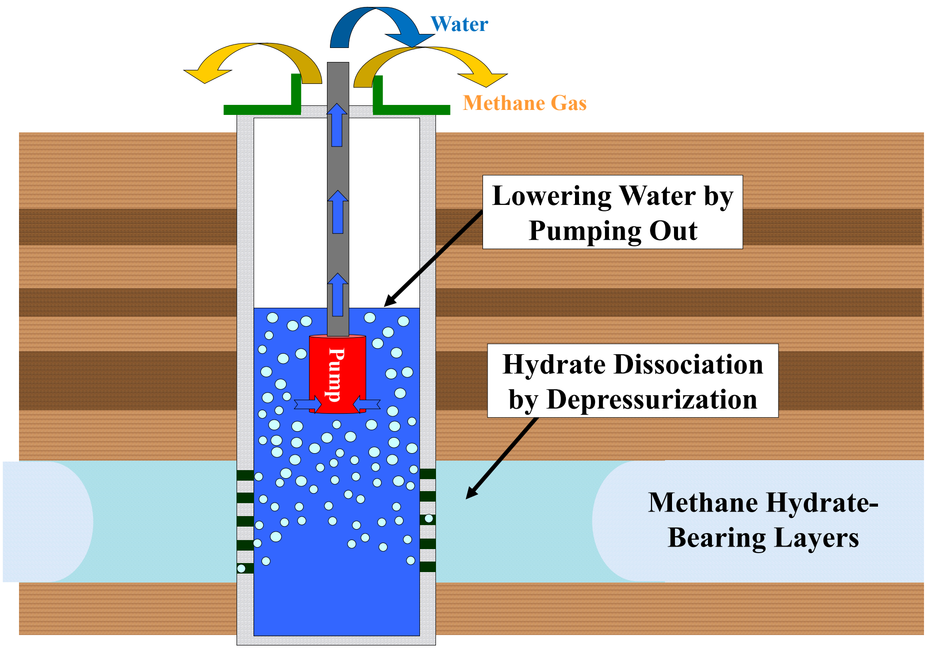


Figure 6-1 Schematic diagram of the depressurization method

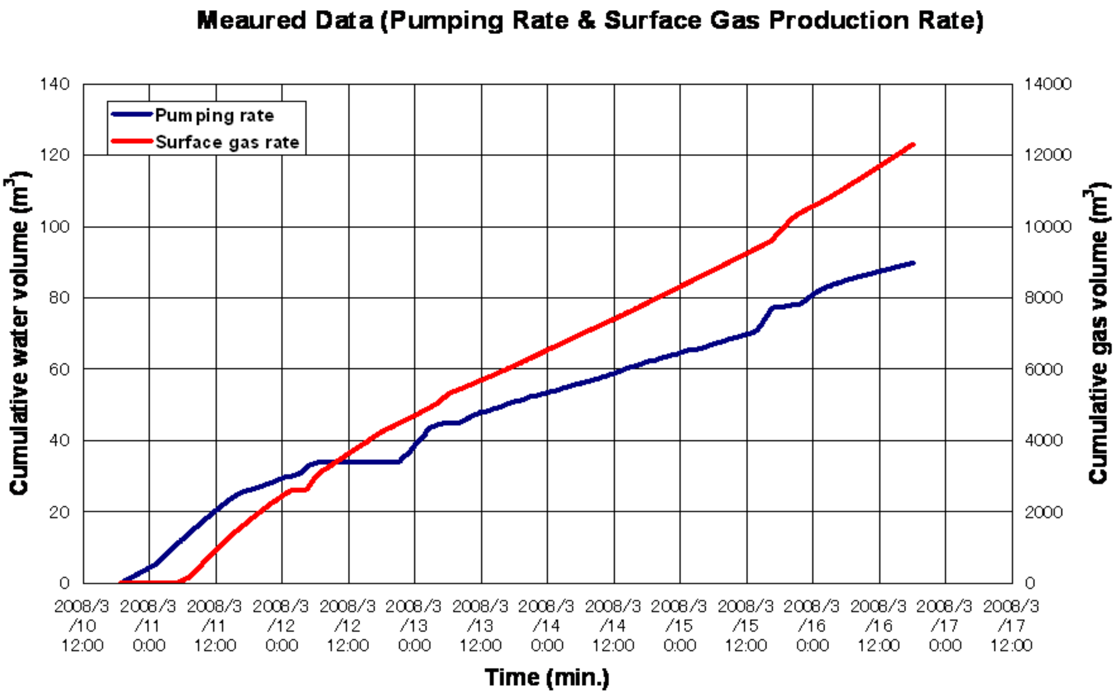


Figure 6-2 Measured production volumes
of cumulative waters (blue line) and gases (red line)

Figure 6-3 Continuously burning gas
(left: the night of March 10, right: the morning of March 16)

Table 6-1 Samples and data obtained from the Second Onshore Gas Hydrate Production Test

Source of Information	Data	Information
First Winter Test (2007)		
Open-hole logging before the test	Resistivity	Hydrate saturation
	Natural gamma ray	Content of clay minerals, lithology
	Neutron scattering cross section	Porosity (φ)
	Density log (gamma ray attenuation)	Density (ρb) -> porosity, hydrate saturation
	Seismic velocity (Vp, Vs)	Formation strength, hydrate saturation
	Neutron capture gamma-ray spectroscopy (ECS)	Mineral composition -> permeability
	Nuclear magnetic resonance log (NMR)	NMR relaxation time -> permeability, porosity, hydrate saturation
	Micro-resistivity borehole image	Hydrate distribution, crack, borehole wall fracture
Cement-bond logging	Impedance ratio of casing and its behind by ultrasonic log	Condition of cementation
	Sonic attenuation by sonic log	Condition of cementation
Cased-hole logging before and after the test	Neutron scattering cross section	Porosity (φ)
	Neutron capture cross section	Formation element composition, porosity (φ)
	Seismic velocity (Vp, Vs)	Formation structure, hydrate saturation
Variables of downhole conditions during the test	Pressure and temperature of the pump suction port	Dissociation behaviour of hydrate
	Pressure and temperature of the pump discharge port	Calculation of fluid flow
	Casing pressure	Calculation of produced gas volume
Samples	Sand sample at retrieving the completion assembly	State of sand trouble
Monitoring outside the casing	Optical fiber thermometer	Borehole temperature
	Fluid flow potential	Fluid movement in the formation
Second Winter Test (2008)		
Variables of downhole conditions during the test	Pressure and temperature above the perforation (memory gauge)	Dissociation behaviour of hydrate
	Pressure and temperature of the pump suction port	Data for the pump operation
	Pressure and temperature of the pump discharge port	Data for the pump operation
State variables of produced fluids	Pressure and temperature of the produced water	Correction for produced water volume
	Pressure and temperature of gas	Correction for produced gas volume
Fluid production rate	Water production volume by the rotating flow meter and the tank measurement	Produced water volume
	Gas production volume by the orifice flow meter	Produced gas volume
Samples	Sand samples in the produced fluid	State of sand trouble
	Samples of produced water	Salinity concentration, origin of produced water
	Gas samples	Origin of produced gas
Monitoring outside the casing	Optical fiber thermometer	Borehole temperature
	Fluid flow potential	Fluid movement in the formation

7. The Production Simulator

The Research Consortium for Methane Hydrate Resources in Japan has been developing Japan's own production simulator (MH21-HYDRES) especially designed for predicting behaviors of methane hydrate-bearing layers. This simulator was improved to the 2-dimensional cylindrical coordinate system model in FY 2000 through the project carried out in the former JNOC based on the 1-dimensional Cartesian coordinate system developed by the University of Tokyo in FY 1999. Since FY 2001, this simulator has been further expanded to the 3-dimensional Cartesian coordinate system model and its functions have been strengthened in the Research Consortium for Methane Hydrate Resources in Japan. As discussed in greater detail below, the five production simulators for methane hydrate-bearing layers are now publicly available worldwide, and the simulator noted above is competitive with others.

The production behaviors of gas and water were predicted in the Second Onshore Gas Hydrate Production Test using this simulator which contributed to the success of the production test by suggesting the basis of the design of the borehole and surface facilities, and preparing task guidelines. It was also utilized in the prediction of the gas production performances, which are the basis for the section "5.3. Objective 3: Selection of methane hydrate resource fields from promising methane hydrate bearing offshore areas and deliberation of economic potential."

7.1 Functions, Features and Achievements of the Production Simulator

The MH21-HYDRES is composed of a variety of calculation routines including the routine to define initial reservoir properties defining the characteristics, properties and conditions of reservoirs, the routine to calculate changes in reservoir properties describing the reservoir properties that change during production, the routine to calculate phase behavior calculating the equilibrium conditions for formations and dissociations of methane hydrate and the formation/dissociation rates, and the routine to calculate phase properties acquiring the state quantity and the enthalpy etc. of each phase. This simulator also utilizes the dynamic local grid refinement method that makes it possible to speed up without losing computation accuracy, the hybrid grid system that makes it possible to calculate the production behaviors of a group of multiple wells group at high speed, the functions of the parallel computation, the calculation functions of the fluid flow in wellbore and the fluid flow in completion interval, and so forth. Additionally, the computation modules were developed for the properties of formation compaction and deformation, the properties of formation and dissociation and the characteristics of permeability, all of which are important factors for expressing the production behaviors of methane hydrate resources. These modules were subsequently incorporated into the MH21-HYDRES as calculation routines. Regarding the characteristics of permeability that is especially crucial for the evaluation of productivity, the vertical and horizontal absolute permeabilities of alternating beds of sand and mud were formulated, and moreover the dependence property of irreducible water saturations and residual gas saturations on sand grain sizes, the effective permeability variations of the methane hydrate occurrences in pore spaces, the relationship between methane hydrate saturations and relative permeabilities and the change in porosity due to compaction and its effect on permeabilities were formulated and built onto the MH21-HYDRES.

The MH21-HYDRES is featured for its development in stand-alone mode especially for the use in the development of methane hydrate resources. Its major difference from a reservoir simulator used for exploitation of conventional oil and gas is that this simulator has the following functions (Figure 7-1).

- Possible manipulation of the five phases such as gas, water, methane hydrate, water ice, and salt
- Able to handle the five components such as methane, nitrogen, water, methanol, and salt
- Introducing the equation of kinetics for methane hydrate formation and dissociation
- Able to handle the exothermic and endothermic behaviors associated with methane hydrate formations and dissociations
- Introducing the equation of kinetics for water ice formations and decompositions
- Able to handle salt precipitation from the salty water phase, salt dissolution to the water phase and associated exothermic and endothermic reactions
- Possible transitions of the three phase equilibration curve of methane hydrate- methane- water (water ice) matched to the calculations of methanol or salinity concentration and the concentrations of methanol or salt
- Possible calculations of the solubility of methane into water phase taking the salinity concentration into account
- Possible manipulations of the configuration of multiple production wells and injection wells including vertical, directional and horizontal wells in methane hydrate-bearing layer
- Possible calculations of the fluid flow in the wellbore taking the exterior formation temperature profile into account
- Possible upgrading for the calculation accuracy and the calculation speed by applying the dynamic local grid refinement method and the hybrid grid system
- Able to handle the boundary conditions of constant pressure, constant flow rate, constant pressure-constant temperature surface and so forth
- Able to handle the lowering permeability due to compaction
- Introducing the effective permeability and relative permeability as a function of methane hydrate saturation
- Able to handle the analyses of the productivity and the production behavior in various basic production methods and their combinations such as the depressurization method, the thermal stimulation method, the thermal flooding, the inhibitor injection method, the nitrogen injection

method

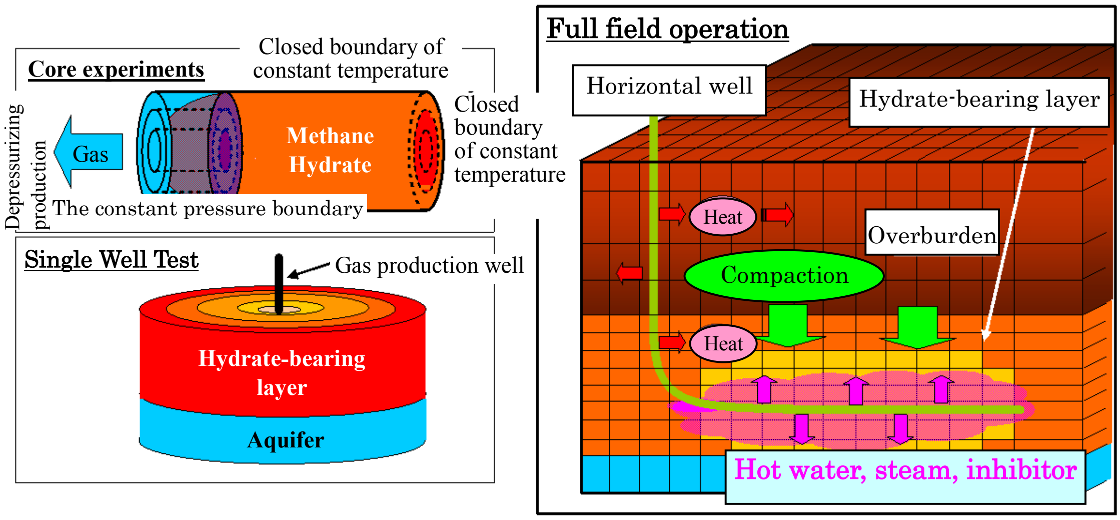


Figure 7-1 Outline of the MH21-HYDRES

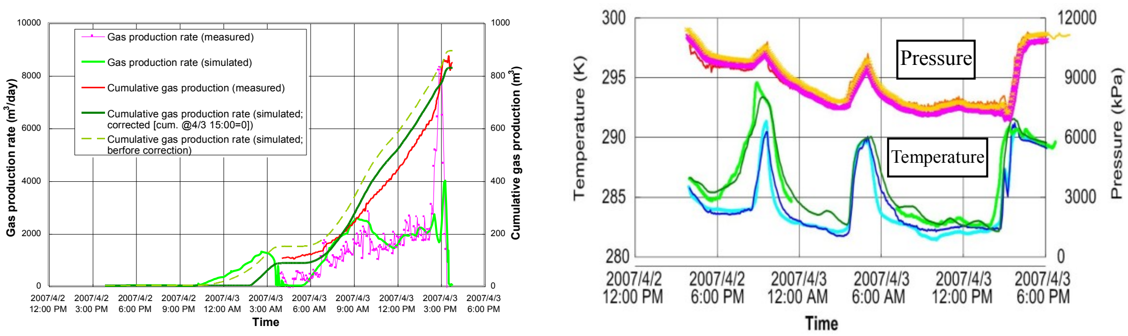
In the calculation module noted above, the independent simulator for the dynamic property analyses was created separately concerning the module of the compaction and deformation property evaluation, and the evaluation of the deformation behaviors accompanied by the production corresponding to the reservoir characteristics and forms became possible (refer to article 8.2. Physical Property Measurements of Methane hydrate-bearing layers (2. Modeling Section)).

MH21 participated in an international project on the comparison of methane hydrate simulators sponsored by the research institute of the US Department of Energy (NETL: National Energy Technology Laboratory) and the US Geological Survey of the Department of the Interior (USGS). A total of five simulators of the MH21-HYDRES as well as the following four participated.

- The TOUGH-Fx/Hydrate: developed by the Lawrence Berkeley National Laboratory (LBNL) based on the TOUGH2 that is famous in the world as a geothermal reservoir simulator.
- The HydrateResSim: opened the TOUGH-Fx/Hydrate v1.0 to the public by the NETL.
- The STOMP-HYD: modified for possible manipulations of gas hydrate from the multi phase fluid flow simulator (STOMP) jointly created by the Pacific Northwest National Laboratory (PNNL) and the Petroleum Engineering Department of the University of Alaska Fairbanks
- The STARS: a commercial oil and gas reservoir simulator especially for predicting reservoir behaviors by thermal methods created by the Computer Modelling Group Ltd. (CMG) in Canada.

This project was began with the coupled problem of one-dimensional heat and fluid flow without methane hydrate, and the seven problems including the reservoir behavior prediction for the depressurization method representing the actual field were investigated with gradually increasing levels of difficulty. The MH21-HYDRES presented the rational calculated results either equaling or surpassing those of the other simulators in all the problems. It also confirmed the possibly adequate calculations of the physical and chemical phenomena necessary for methane hydrate simulators in terms of the methane hydrate formations and dissociations, the water ice formations and decompositions and so on, and the possibly adequate expressions of the two-phase fluid flow phenomena after methane hydrate was dissociated. In addition, the calculations converge adequately in the problem of behavior prediction of the field scale production, and also present the excellent results in perspective of computational stability. At present, it has prerogatives to the other simulators.

The (MH21-HYDRES) simulator was used to carry out intermediate interpretation and the posteriori interpretation for the results of the Second Onshore Gas Hydrate Production Test, and the production behaviors were analyzed and evaluated. Regarding the First Winter Test, the result of the production test has been approximately reproduced by adjusting the reservoir parameters and assuming the permeability increase due to sand production in the adjacent formations around the well and the nonsteady wellbore fluid flow in the matching simulation (Figure 7-2), although the details of functions of the simulator have not been sufficiently verified due to the short production period of approximately 12.5 hours. Regarding the Second Winter Test, the gas production rate changes during the test period of approximately six days and the gas and water production rates under the constant bottom hole pressure were reproduced, and moreover the formation temperature in the methane hydrate dissociation zone estimated by the simulation was consistent with the measured bottomhole temperature. Furthermore, the relative permeabilities to gas and to water in the field were evaluated by using the matching simulation of the production test, and the improvement of overall accuracy of the production simulator was accomplished.



(a) Matching of the gas production volume

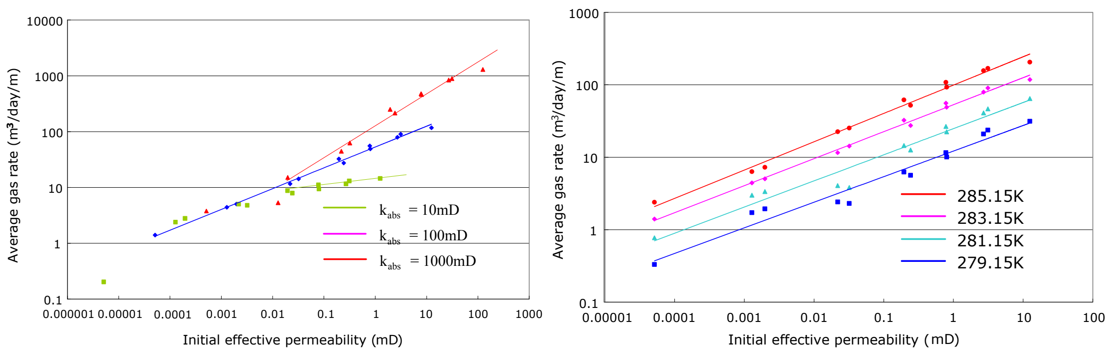
(b) Matching of the borehole temperature and pressure

Figure 7-2 Matching results of the First Winter Test of the Second Onshore Gas Hydrate Production Test

7.2 Evaluation of the Production Method by MH21-HYDRES

By utilizing the reservoir model surrounding the well made at selecting the methane hydrate resource field in the eastern Nankai Trough (refer to article of 5.3. Objective 3: Selection of methane hydrate resource fields from promising methane hydrate bearing offshore areas and deliberation of economic potential), the production behaviours and energy efficiency by various production methods were evaluated.

- Thermal methods such as the thermal stimulation method and the thermal flooding etc. on their own were assessed to have low levels of energy efficiency and only able to be used in the distant future. In addition, many future issues remain to be dealt with from the viewpoint of the gas sealing capacity of the formation by means of core test results and the dynamic property.
- Generally the depressurization method should be applicable (Figure 7-3 (a), (b)) when the permeability and the reservoir temperature are high, and the reservoir characteristics in the eastern Nankai Trough area are satisfied.
- The recovery factor drops away as the heat transfer from the surrounding areas cannot keep up with the compensation of heat absorptions due to methane hydrate dissociation in the case of the thick concentrated zones.
- The combination of the thermal stimulation methods and the depressurization method is more adequate when the methane hydrate-bearing layers are thick or the increasing the recovery factor is aimed in the low temperature reservoirs.
- The lowering of the energy efficiency is inevitable by combining these thermal stimulation methods, and at that point, development of more effective combinable methods will be considered necessary in the future.

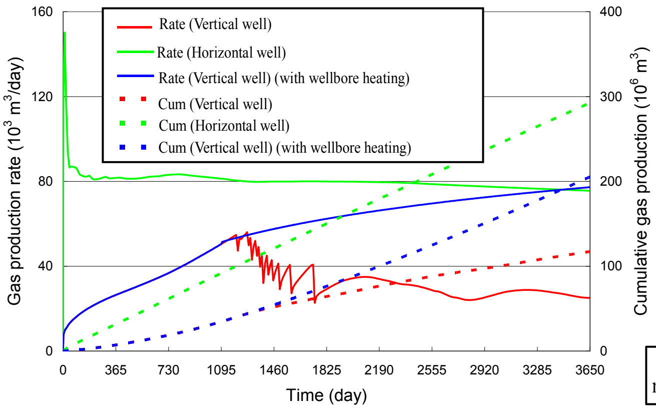


(a) Relationship between the initial effective permeability and the productivity

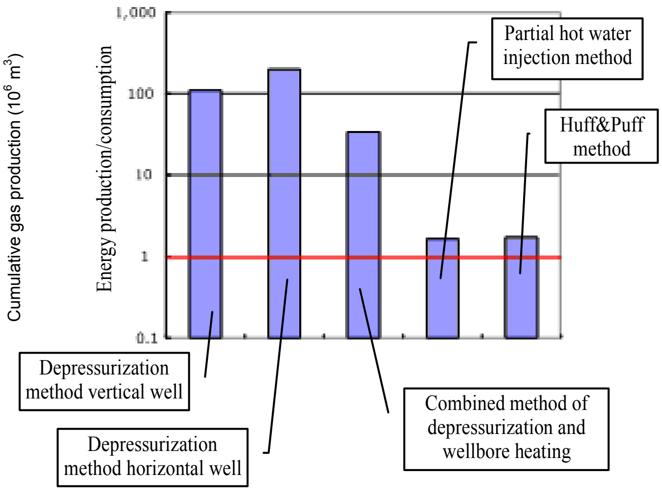
(b) Relationship between the reservoir temperature and the productivity

Figure 7-3 Relationships between the productivity using the depressurization method and the initial effective permeability and the reservoir temperature

Based on the analysis results, after the energy efficiency and the simple provisional calculation of the economic potential were done, the economical potential seems promising because the high energy efficiency in the depressurization method (horizontal well), the depressurization method (vertical well) and the combined method of the depressurization method and the wellbore heating method is expected and the payout time is early (Figure 7-4).



(a) Example of the prediction results of gas production behavior by the depressurization method



(b) Example of the calculation of the energy efficiency

Figure 7-4 Example of the prediction results of gas production behavior in the single well using the simple Nankai Trough model

The "Depressurization method" is carried out to depressurize the pore pressure of methane hydrate-bearing layers through perforations with reduction of the bottomhole pressure by lading water in the well using pumping. For this reason, the energy directly expended for production is motive energy of the pump, and subsequently, a high level of energy efficiency is theoretically able to be expected. Methane hydrates are dissociated into gas and water by depressurizing the pore pressure of the methane hydrate-bearing layers that are less than the equilibrium curve, and gases and water are produced by flow from the subsurface layers into the production well in which pressure is low. As the dissociation in the methane hydrate-bearing layers is accelerated when subjected to heat, the dissociation progresses at the point where heat is supplied (Figure 7-5). It is difficult to continue the process of dissociation near the center of the methane hydrate-bearing layers where there is an insufficient supply of heat. The effective permeability increases due to the lowering of methane hydrate saturation in pores where dissociation progresses, and dissociation will be accelerated furthermore by making depressurization occur more effectively. As noted above, the dissociation in the methane hydrate-bearing layers advances heterogeneously, and the parts contacting the methane hydrate-free layers above and below the methane hydrate-bearing layers may preferentially contribute to production.

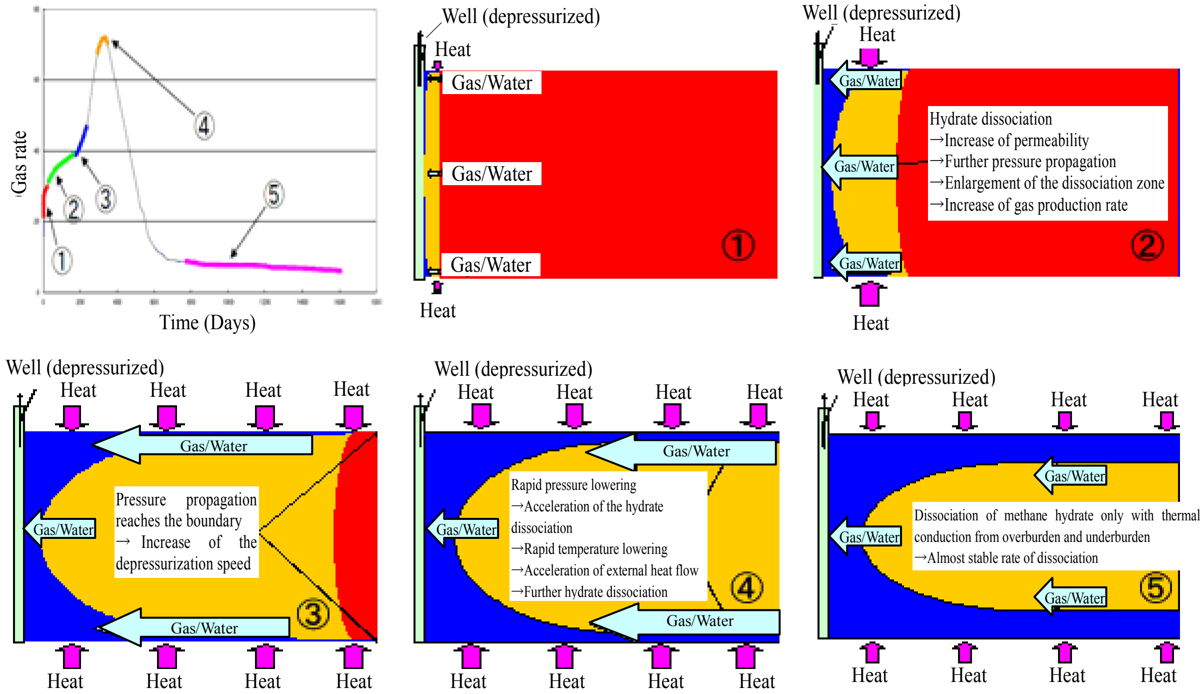


Figure 7-5 Behavior of gas production by the depressurization method accompanied with the heat supply from the adjacent formations and the change of the methane hydrate dissociation zone

In the eastern Nankai Trough area, the potential heat in alternating beds of sand and mud will contribute to a certain amount of the production and recovery factor without any artificial heat supplies, however the heating etc. may be considered necessary for increasing the recovery factors and productivity in low temperature reservoirs. The depressurization method may play a pivotal role regardless of what we adopted, including the human-induced heat supplies shown in Figure 7-6.

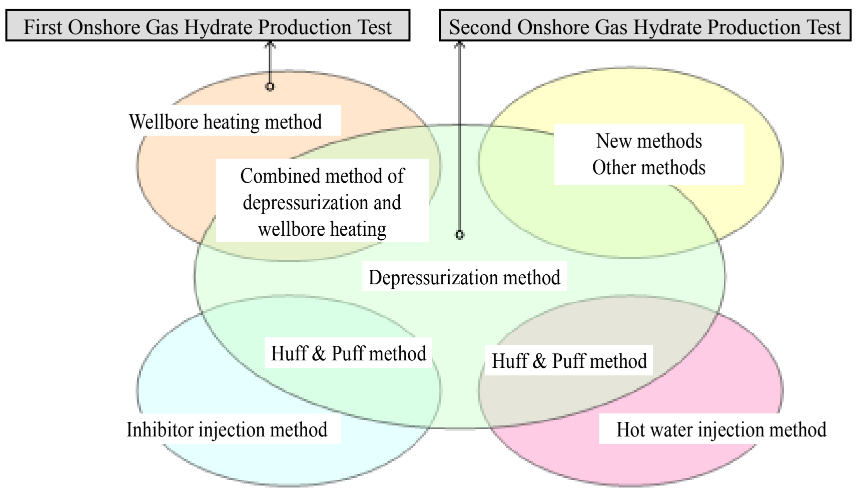


Figure 7-6 Relationship among the various production methods

The depressurization method can essentially maintain productivity over the long term unless the effective permeability and absolute permeability of the reservoirs decreases. However, decreasing the permeability can be predicted from the influences of the skin formation caused by the accumulation of silt constituents around the wellbore in the process of production and the compaction accompanied by the depressurization. In addition, increasing of the water production volume can be predicted to disturb effective propagation of depressurization to the reservoirs due to the water coning when the permeable water-bearing layers overlie and underlie the reservoirs. It is necessary to quantitatively understand these factors of production damage.

8. Predominant Results of Items Above

In the R&D program "V. Contents of Technology Developments," the contents of technological development are described in the five sections. The status of the achievements in each section of the technological development contents will be submitted as a self-evaluation in the final assessment of Phase 1 that will be carried out in FY 2008 by METI. The predominant results of them are comprehensively described in the articles of "5. Status of Achievement of R&D Program Goals," "6. Achievements of the Onshore Gas Hydrate Production Test," and "7. The Production Simulator." As many more achievements have been obtained from the development of recent research other than the results described in these three articles, the selected achievements in those will be summarized in the order prescribed in the R&D program.

8.1 Clarification of the Methane Hydrate Accumulation Mechanism and the Origin of Methane Gas (1. Exploration Section)

The objective of this study is to contribute to the improvement of accuracy of the methane hydrate resource assessment (the presumption of the concentrated zones) around Japan by targeting the methane hydrate distributed below the seafloor in the Nankai Trough by means of elucidating the process of how the present appearance of methane hydrate distribution has been made and what the controlling factors are.

(a) Methane Generation and Origin

According to the results of the geochemical analyses for the core samples obtained from the METI Exploratory Test Wells "Tokai-oki to Kumano-nada," all of the gases contained in methane hydrates recovered from the eastern Nankai Trough area have been confirmed to be mainly composed of biogenic methane. The total organic carbons (TOC) at the depth of methane hydrate existence in the eastern Nankai Trough are approximately 0.5%, which is not sufficient for forming the concentrated zones in terms of the mass balance. Although the biogenic gas composing methane hydrates are estimated to have been generated in the relatively shallow depths after deposited, it is nearly apparent that they have not been generated only in the present contained formations based on the occurrences of methane hydrates and the mass balance of carbon, and that the migrations and accumulations of methane from the deeper formations have occurred. Regarding the mechanism behind the above, after biogenic methanes generated at the time of deposition of the accretionary sediments were buried with the sediments by the accretionary movement, the dissolved methanes become gases when their dissolved contents exceed the saturated dissolved concentration. It should be estimated that they have migrated and accumulated through faults, high-permeable sandy layers, unconformities and so on to the high-permeable sandy layers, and that they have formed the methane hydrate-bearing layers.

(b) Methane Hydrate Formations

By the analyses of the MH formation experiments, the methane hydrate saturations were found to relate to the specific surface area and the pore diameter distributions of the sediments. As the saturations of the sediments predominantly with smaller pore diameters (clay to fine-grained silt) are low and those of the well-sorted sediments predominantly with larger pore diameters (coarser than fine-grained sand) are high, it is estimated that the free water volume containing in sediments may affect the methane hydrate saturations.

(c) Methane Hydrate Reservoir Characteristics and Occurrence

According to the analyses of the core samples obtained from the METI Exploratory Test Wells "Tokai-oki to Kumano-nada," it has been understood that the methane hydrate concentrated sand layers are composed of fine- to very fine-grained sands, and that the porosities and permeabilities of them are high. It is assumed that these sandy layers have not significantly suffered from the burial diagenesis. Moreover, the analyses of the sequence stratigraphic studies by means of the seismic data and the downhole well log data were carried out, and the shapes of the submarine fans of each depositional sequence were rebuilt. Subsequently, the methane hydrate-bearing layers in the eastern Nankai Trough are found to distribute in the sandy layer parts of the turbidite sand and mud alternation layers forming the submarine fans.

(d) Geological and Geochemical Environments of the Shallow Formations and Phenomena on Seafloor Surface

When the distribution of the SMI depths indicating the methane flux near the seafloor were compared to the BSR distributions, the significant relationships between them have not been recognized. The reason for this is considered that fluid containing methane are not controlled by the simple upward diffusion, but are considered to have migrated to the seafloor by selecting the high permeable migration paths through the local faults and the high permeable sandy layers with horizontal continuation.

(e) Investigations by the Numerical Simulation

A case study was attempted based on data from the eastern Nankai Trough using the newly developed one-dimensional methane hydrate formation simulator. As a result, it was indicated that the advective flows of methane from the deeper formations are an especially crucial factor for controlling the formation of the concentrated zones, and that the sediment properties, the volume of methane supply and the tectonic movements are important as factors controlling the methane hydrate concentration change in the methane hydrate-bearing layers.

Meanwhile, the two- and three-dimensional methane hydrate accumulation simulator (SIGMA-MH) was created based on the simulator for integration of generation, migration, and accumulation of oil and gas owned by the JOGMEC, and the case study was done for the Nankai Trough area (the two-dimensional profiles of the Tokai-oki and the Daini-Atsumi Knoll). According to the result of the sensitive analyses, it was realized again that the sea level changes in the past have made the methane hydrate stability zone changed significantly, and that they strongly influence the distribution of methane hydrate accumulations.

8.2 Physical Property Measurements of Methane hydrate-bearing layers (2. Modeling Section)

1) Establishment of the Core Test Technology Basis at In-Situ Condition

The methane hydrate-bearing layers are contained in the pore spaces of sandy layers in alternating beds of sand and mud below the seafloor in very deep waters, which is an environment in which temperatures are approximately 10 degrees C and pressure is greater than 10MPa (refer to Figure 2-1). The methane hydrate-bearing layers are overburdened from the sea surface to the formation, and the fluids in the pores are under the formation pressure close to the hydrostatic pressure from the sea surface to their depth. The technology basis for the core tests at the in-situ conditions replicating these environmental conditions was established. The high-pressure test apparatus of the core holder used for analyzing and evaluating various basic physical properties, mechanical properties, dissociation properties of core samples (cylindrical geological samples) is developed, and is available for the installation of a thermometer and a pressure gauge etc. outside and inside of the samples depending on the purposes of the tests. In addition, it is specified for explosion protections compliant with the high-pressure gas safety law. The evaluation tests on the core samples obtained from the METI/MITI Exploratory Test Wells and the artificial methane hydrate sediment core were undertaken at the in-situ conditions to the most extent. A part of these core test results are summarized in the section 5.1.

2) Development of the Consolidation and Deformation Analysis Simulator of Methane hydrate-bearing layers

While the methane hydrate is solid, it dissociates into methane gas and water. Therefore, an analytical tool was developed for the consolidation and deformation behaviours of the methane hydrate-bearing layers accompanied by methane hydrate exploitation. As the mechanical properties of the methane hydrate-bearing layers have until now been unclarified, it has been difficult for the analyses by the existing finite element method to predict the consolidations and deformations of the methane hydrate-bearing layers to a sufficient level of accuracy.

As part of the development of the production simulator, the module for the consolidation behavior evaluations was created, of which data were built into the production simulator, MH21-HYDRES. As a self-sustained type of the module for the consolidation behavior evaluations, the “consolidation and deformation analyses simulator for methane hydrate-bearing layers” COTHMA (Coupled thermo-hydro-mechanical analysis with dissociation and formation of methane hydrate in deformation of multiphase porous media) was developed.

By utilizing COTHMA, the time-dependent changes for the formation consolidations and stress states associated with the production in the surrounding areas around the well were investigated based on the representative geologic sections, stratigraphies, formation thicknesses and dips etc. These results provide the necessary information for drilling and completing the wells.

3) Establishment of the Imaging Analysis Technology of Physical Property and Dissociation Characteristics

In order to determine the porosities and methane hydrate saturations of core samples, the method determining these physical properties by the image analyses was developed using the micro focus X-ray CT instrument with a high special resolution (finer than 10 μ m). With combining the cooling method to blow the gas gasified from liquid nitrogen, the method identifying the sand grains composing the sandy sedimentary formations and analyzing the porosities in a high accuracy at the atmospheric pressure and lower than -100 degree C was developed. The brightness value distributions of the CT images was decomposed into four components such as “sand grain,” “methane hydrate,” “water,” and “free gas,” and the saturation of methane hydrate was calculated from the area ratio of methane hydrate to pore space (Figure 8-1). Those methane hydrate saturations estimated from this CT image are highly consistent with the direct values obtained from the dissociation experiments.

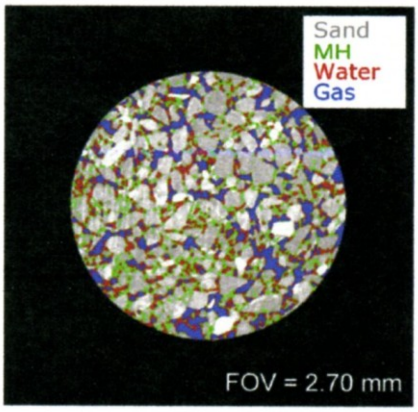


Figure 8-1 Four-component discrete image of the sandy core obtained from the METI Exploratory Test Wells “Tokai-oki to Kumano-nada,” sand, methane hydrate, water, and methane gas

To clarify the occurrence of methane hydrate contained in the pores, the direct observation method using an electron microscope was developed. By taking into account the character of methane hydrate that is difficult to observe in high vacuum conditions due to its high saturated vapor pressure, this method uses the field emission scanning electron microscope combined with the differential pumping equipment-attached low-vacuum specimen room and the low-temperature stage, and subsequently, steady observations are expected. By using the Energy Dispersive X-ray Spectrometer (EDS), the methane hydrate is discriminated from the frozen pore water. As a result of the analysis, it is elucidated that most of the methane hydrate particles come in contact with sand grains.

In order to construct the model clarifying the methane hydrate dissociation process in core samples by thermal stimulations or depressurizations, the method visually observing the expansion process of the methane hydrate dissociation area and the fluid flow process of gas and water derived from the dissociations at the in-situ conditions was developed. This is the core testing method using the X-ray CT instrument characterized by high speed scanning and imaging system using the cone-beam method with the rotatable X-ray source and flat panel detector around the tri-axial core holder, a maximum tube voltage of 130kV, a maximum tube current of 20mA of the X-ray source, and a visualization sectional area of 100x100mm. This is also available for the repeatable observations with a slice pitch of 0.25mm, a single scan time of 40 seconds, and two-minute intervals. By installing the heat exchange bath circulating hot brine in the fixed end plug of the core holder, the end face heating and the hot water injection experiments are available with a good response of the core temperature.

Figure 8-2 shows the high-speed X-ray CT images indicating the dissociation processes of the depressurization method, the wellbore thermal stimulation method, and the hot water injection method from the left. The following is assumed: In the depressurization method, the undissociated area has a cannonball shape that reveals that dissociation proceeds with a lowering of the specimen temperature due to hydrate dissociation accompanied by the external heating. In the wellbore thermal stimulation method, the dissociation front moves only in one direction with dissociation occurring from the heating end. In the hot water injection method, the gas pool occurs adjacent to the channel of hot water, and the breakthrough of the injection water makes the gas production speed accelerate. Depending on the dissociation conditions, it is necessary to increase the injection pressure more as a result of the lowering the permeability due to the regeneration of methane hydrates.

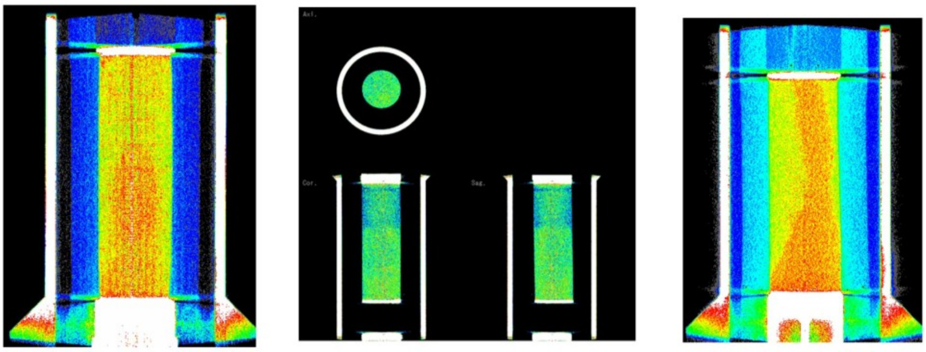


Figure 8-2 High speed X-ray CT visualized images indicating the dissociation processes of various decomposition methods

(the sample: artificial MH core, the depressurization method, the wellbore thermal stimulation method, the hot water injection method from the left, 30-40 minutes after dissociation began, the depressurizing face and the wellbore heating face are the upper end, the hot water injected from the bottom, the outlets of production fluid are at the upper end)

8.3 Technology of Well Drilling and Completion (4. Development Section)

Most of the methane hydrate-bearing sediments exist at depths ranging from 200 to 500m with water depths ranging from 800 to 2,000m in the eastern Nankai Trough area. While the water depths of some overseas fields targeted for conventional oil and natural gas exceed these water depths, such shallower depths below the seafloor are rare. When the methane hydrate-bearing sediments are targeted for development, it is necessary to assure sealing capacity to prevent gas and water from flowing through the apertures between the casing and the formations in drilled and completed wells in unconsolidated sediments from more recent geologic ages. There are some issues that differ from those related to the development of conventional oil and natural gas. In the METI Exploratory Test Wells “Tokai-oki to Kumano-nada,” demonstration experiments were carried out focusing on the following five points.

- Drilling fluid technology (the fluid types and the borehole wall stability)
- Cementing technology
- Technologies of formation pressure and formation fracture pressure measurements
- Downhole measurement (measurements of borehole size, borehole pressure and borehole temperature)
- Horizontal hole drilling technology

These demonstration experiments were conducted at a water depth of approximately 1,000m in the Daini-Atsumi Knoll area, and two wells were drilled (Figure 8-3). The experimental well 1 is a vertical well that was drilled to a depth of 404m below the seafloor. The cementing technology and the technologies of formation pressure and formation fracture pressure measurements were primarily experimentally demonstrated in this well. The experimental well 2 was demonstrated to drill a horizontal section for a distance of 100m in the methane hydrate-bearing layers at a depth of 340m below the seafloor. Moreover, the technologies of drilling fluid and wellbore monitoring were experimentally demonstrated in both wells.

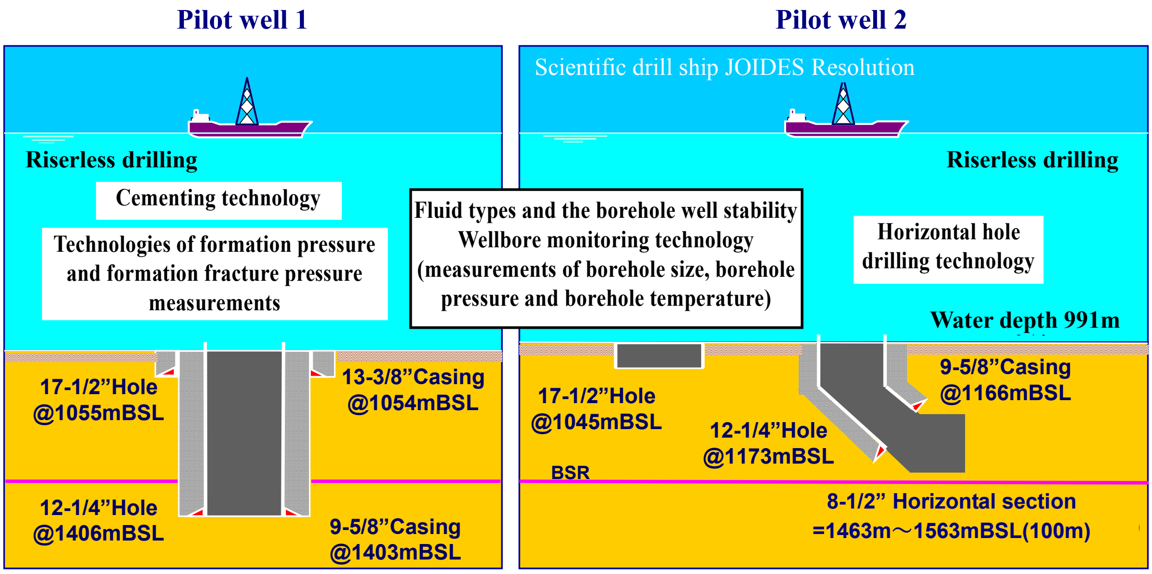


Figure 8-3 Schematic diagrams of the experimental well 1 and 2 (BSL=below sea level)

From these demonstration experiments, the applicability of well drilling and completion technologies for offshore methane hydrate production was confirmed.

Regarding the drilling fluid, borehole wall stability has been maintained by using the two types of the KCl-polymer mud and the sepiolite drilling mud of which there are no significant differences, but the borehole enlargements were recognized in the layers other than the methane hydrate-bearing zone. Regarding downhole measurement technologies, borehole sizes, borehole pressures and temperatures were rmonitored during the drillings, and the results were effectively for the used operations. Furthermore, the drilling of horizontal wells, even in shallow unconsolidated sediment was demonstrated to be viable. Although formation pressures and formation fracture pressures were measured, attention was required to be paid to interpreting the data due to the possible effects of methane hydrate dissociation. Remaining future issues involved cementing technology, and it was learned that it will be necessary to develop technologies both in the cement materials and cementing operations.

8.4 Development of Technologies to Monitor Seafloor Environment and The HSE Inquiry (5. Environment Section)

1) Development of Technologies to Monitor Seafloor Environment

In order to evaluate seafloor environmental impacts associated with the exploitation of methane hydrate, it is necessary to monitor the environmental impacts of the gas leakages and the sediment deformations, etc. broadly over the long term. In Phase 1, the development of elemental technologies of the measurements such as the technique for detecting the ground displacement and the technique for detecting the gas leakage, etc., the development of the monitoring network construction technology to integrate them, and the development of the environmental index mapping technique by the deep-towing sensors and the ROV will be carried out.

- In order to monitor environmental impacts during the offshore production test, the basic design of the integrated monitoring system with various sensors (the prototype system) was completed.
- The existing dissolved methane sensor (the METS sensor) was improved by reducing the response time by more than 50%, and stability was improved. We have developed the prototype sensor, and then, confirmed by laboratory experiments that the sensor can be used under hydrostatic pressure equivalent to the pressure at the water depth of 2,000m, that the lower measurement limit of concentration is similar compared to that of the conventional METS sensor, and that response and the stability are improved. Based on these data, we clarified its performance and specifications.
- As for developing the new dissolved methane sensor (the IR Absorption based Dissolved Methane Sensor (IRAMES)), we have developed basic technology capable of detecting the trace-dissolved methane that cannot be detected by the conventional METS sensor. The basic system (the experimental system) was composed of the separation membrane and the infrared absorption technology and so on. We had designed and manufactured the experimental system, and verified its performance. As a result, the lower measurement limit of concentration became 3.4nmol/L (at 4˚C) and less and this value was a half of the conventional METS sensor.
- In order to detect the methane leakages on the seafloor early, an experimental system for the totally integrated and automated system for in-situ gene analysis of microbes (IISA-gene system) utilizing the biomarkers was developed. Regarding the biomarkers, genes that characteristically exist in methane oxidizing bacteria and that occur in abundance in the methane seep area were selected, and an adequate detection method utilizing the experimental system was established.
- In order to detect methane bubbles in seawater, we inquired regarding the specifications and past records of performances of existing sensors that utilize ultrasonic waves. The method of the wide-area monitoring system using ultrasonic wave and the utilizing sensor were decided, and the basic design of the verification system was created.
- In order to detect the methane gas in an atmosphere, the basic design of the monitoring system using light absorption characteristics of methane gas was created.
- In order to detect the ground deformation of the seafloor, the sediment deformation monitoring system using an accelerometer was developed, and experimental demonstration tests were carried out in the laboratory and the terrestrial landslide areas. Prototype system that reflected the obtained results was created. Methods to supply power and transfer data in order to build onto the integrated monitoring system were investigated, and power supply and data transfer across the pressure vessel were confirmed to be practicable.

2) HSE Inquiry

The HSE management system is an administration system aimed at health, safety and environmental conservation. Considering the fact that the commercial production of methane hydrate is producing hydrocarbons in waters over 1,000m deep, this will be an unprecedented project. Knowledge about ensuring safety is insufficient both in relevant and supervisory organizations and it should be necessary for it to be compensated for as far as is possible.

- Regarding the investigation of safety aspects, articles about safety management issues in publications and from interviews based on experiences in developing deep water oil in the Gulf of Mexico and in drilling the METI/MITI Exploratory Test Wells targeting methane hydrates in the surrounding ocean areas of Japan were summarized.
- Requirements for safety management issues adopted in various countries that have many cases conformable to the methane hydrate exploitation were inquired about and summarized.
- The various theories concerning environmental impacts caused by methane hydrates were boxed up, and these results were stored in the database (HYDREAMS) for public use in order to respond to inquiries from individuals and organizations.
- Management methods for environmental impacts chiefly from environmental impact assessment systems in Norway, U.K., Australia and Canada were inquired about through publications and interviews. Based on these results, environmental impact assessments envisaged in offshore production tests were speculated from the viewpoint of global trends.
- Case examples of environmental impact assessments in similar operations such as those related to the exploitation of oil and natural gas at home and abroad, methane hydrate exploitation of the US Department of Energy, risk assessments involved in large-scale developments, and the methane hydrate-related publications were inquired about for the purpose of learning about global environmental risk assessment methods. The selection of risks that should be evaluated in the development of methane hydrates and risk assessment methods were arranged, the achievements of which are reflected in article 5.4 3).

9. Perspective for the Future from Phase 1 Achievements

The following items are proposed as the goals of Phase 1 to achieve in the section of the R&D program “IV Program Schedule for the Goals Achievement.”

- Implementations of basic research (exploration techniques, basic physical properties, dissociation and formation techniques, and so on)
- Achievements of the optimization of the methane hydrate exploration technology
- Understandings of the resource-bearing offshore areas and volume of resources
- Selections of the methane hydrate resource fields that can become targets of the offshore production test in Phase 2
- Investigations into gas recovery techniques for methane that rises to the surface continuously from the dissociation of methane hydrates, based on experiences from onshore production tests

The achievement statuses of these research issues have already been briefly described in each section above, all of which have been accomplished except for the production period finishing in 6 days in the onshore production test. As described in section 6, the second winter test of the Second Onshore Gas Hydrate Production Test in March 2008 was continued to the originally planned time limit that was set up by taking the inherent constraints of the operation period in the Arctic region without any budgets or infrastructure into account, and was finished. Inasmuch as this situation, the goals of Phase 1 have almost been achieved. It should be considered that the preparations for transition to Phase 2 are now complete.

9.1 The issues of Developing Technologies of Phase 2

The issues of developing technologies in Phase 2 derived from the evaluations of the results in Phase 1 are summarized in Table 9-1.

Table 9-1 Issues of developing technologies of the Phase 2

1. Enlargement of Resource Assessment Targets	1.1 Enlargement of the targeted ocean areas (2D•3D seismic surveys, test wells, implementation of the seafloor survey) 1.2 Evaluation technology for the methane hydrate resource fields (sandy layers, non-sandy layers with pore filling methane hydrate) 1.3 Elucidation of the methane hydrate system (research for the accumulation mechanism of methane)
2. Establishment of the Base Technology for Methane Hydrate Production	2.1 Long-term production test (onshore desired) 2.2 Offshore production test (refer to the article of 9.2) 2.3 Reservoir evaluation technology (detail geological model, reservoir characterization, monitoring of physical property etc.) 2.4 Development of the offshore production technology (subsea and downhole equipments, well completion technology etc.) 2.5 Optimization technology of the production plan (improvement of simulator in a higher accuracy, technique of the economic potential evaluations etc.) 2.6 Improvement of the economic potentials (optimazation of the production system, method of the productivity enhancements etc.) 2.7 Comprehensive evaluation accompanied with the long-term production (change in the methane hydrate-bearing layers, environmental impacts etc.)
3. Establishment of the Environmental Impact Assessment Method	3.1 Implementation of the environmental impact assessment for the Offshore Production Test 3.2 Upgrading of the environmental impact prediction model (biological influence, sediment deformation) 3.3 Development of the monitoring technology (sensor, integrated monitoring system) 3.4 Investigation of applicability of the safety management and environment administration system corresponding to the Offshore Production Test 3.5 Evaluation and investigation of the global environmental risk assessment

The long-term production test will be conducted on land, and it is desired that any issues should be solved in order to ensure successful implementation of the offshore production test, and that testing technologies can be improved. It is envisaged that this onshore production test will be carried out as part of international collaborative research similar to that utilized in previous production tests. Either on land or offshore, please note the following items that are to be taken into consideration when planning the long-term production test:

(1) The period appropriate to the characteristics of the targeted methane hydrate-bearing layers should be selected. In the depressurization method, the gas production rate is predicted by the production simulator to increase as time elapses. According to the observations of the production test, it is necessary to enhance the precision of the simulator quantitatively by comprehending characteristic production behaviors. Quantitative measuring of production volumes of gas and water to a high degree of accuracy and the maintaining of bottom-hole pressure at the planned value and so forth are important items that are to be investigated.

(2) Checks to determine whether borehole maintainability is able to meet the requirements of the long-term production tests should be investigated and designed. In the Onshore Gas Hydrate Production Test in March 2008, the installation of a sand screen to prevent sand trouble that affected methane hydrate-bearing layers in the previous year was confirmed to be effective. Achievements leading up to the solution of unknown issues such as the deformations of the

methane hydrate-bearing layers caused by long-term production, stress changes in the surrounding formations around the well, changes in retention capability of seal capacities of the cement behind the casing, and so on, is anticipated.

9.2 Preparation for the Offshore Production Test

The achievements of Phase 1 positioned to prepare for the implementation of the offshore production test that is the main task in Phase 2, and future issues to investigate in Phase 2 are summarized in Table 9-2.

The previous record of the production tests in the conventional oil and natural gas exploration in the surrounding offshore areas around Japan is the test in the gas-bearing layer at the depth greater than 3,000m (below sea level) with the water depth of 857m carried out in the MITI Exploratory Test Well "Sanriku-oki" in 1999. It is anticipated that production tests in methane hydrate-bearing layers are to be undertaken under arduous conditions such as in water depths of approximately 1,000m and formation depths of approximately 1,200m (below sea level), which have never been carried out before in or around Japan. The implementation of offshore production tests targeting the methane hydrate-bearing layers has a presupposition that we should take full advantage of the conventional oil and natural gas exploitation technologies in offshore environments. However, there is an aspect in the production tests of the methane hydrate-bearing layers that differs from those of the conventional oil and natural gas layers, and the appropriate design is ascertained to be necessary from past experiences of onshore production tests. The offshore production tests in the methane hydrate-bearing layers envisaged in Phase 2 is considered to be the first trial of its kind in the world. In addition to the technologies used in the conventional oil and natural gas layers, our unique technological issues that are adequate to methane hydrate-bearing layers should be steadily solved, and approximately 3 years will be necessary for research and preparation in order to carry out the offshore production tests safely, depending on the technical issues involved.

Regarding expedients to resolve various issues, the real equipment-size study matching the actual field site will be necessary besides other kinds of laboratory research. The following facilities and opportunities are considered to become research settings.

(1) Real equipment-size tests in drilling the onshore METI Exploratory Test Wells, etc.

(2) Real equipment-size tests as the demonstration experiment tests in the METI Exploratory Test Wells

(3) Field tests in the onshore production tests

The achievements in Phase 1 and the technical issues in Phase 2 regarding the unique technological issues of the offshore production tests in the methane hydrate-bearing layers are summarized in Table 9-2.

Table 9-2 Current situation and issues related to preparation for the offshore production test

	Results in Phase 1	**Issues in Phase 2**
1 Approach to the results of Onshore Production Tests		
1.1 Provision of sand troubles	Effective in the Second Onshore Gas Hydrate Production Test	Applicability to the offshore MH layers
1.2 Monitoring system in wellbore	Effective in the Second Onshore Gas Hydrate Production Test	Applicability to the offshore MH wells
1.3 Provision for prevention of hydrate formation in borehole and production riser	Borehole provision confirmed in the Second Onshore Gas Hydrate Production Test	Applicability to the offshore MH wells
1.4 Method of kill well	Implemented in the Second Onshore Gas Hydrate Production Test	Investigation of the specific procedures in offshore wells
1.5 Method of well abandonment	Implemented in the Second Onshore Gas Hydrate Production Test	Investigation of the specific procedures in offshore wells
2 Prediction of bottom-hole pressure, water and gas production volume, and production behavior by simulation	Succeeded in 6-day simulation prediction in the Second Onshore Gas Hydrate Production Test	Long-term simulation, Application to the multiple alternating beds of sand and mud
3 Test evaluation of seal capacity between well and borehole wall, and well completion		
3.1 Casing program	Analysis of the demonstration experiment results in the METI/MITI Exploratory Test Wells	Investigation of the offshore MH layers characteristic program
3.2 Cementing material and injection technique	Analysis of the demonstration experiment results in the METI/MITI Exploratory Test Wells	Investigation of the offshore MH layers characteristic issues
3.3 Calculation of MH layer consolidation accompanied with production	Investigating by the laboratory core experiments and simulations	Investigation by experiments and simulations for the offshore MH layers
3.4 Calculation of relative displacement between formation and borehole accompanied with production from the bottom of MH layer to the seafloor	Investigating the deformations from the upper MH layer to the seafloor by cores retrieved from the METI/MITI Exploratory Test Wells	Comprehensive investigation combining to cementing
4 Solution of issues related to adoption of ESP dropping into the borehole	ESP applicability confirmed in the Second Onshore Gas Hydrate Production Test	
4.1 Inquiry of adoption examples in the production tests in the offshore wells	Under investigation	Investigation of specific ESP in offshore wells
4.2 Issues when used in the production tests in the offshore wells	Under investigation of problems of ESP use from floater	Investigation and provision of specific issues in offshore wells
4.3 Provisions at the time of an emergency in the production tests	Investigating the results of the Second Onshore Gas Hydrate Production Test	Investigation of specific provisions in offshore wells, investigation and provision of the equipments
4.4 Issues at the time of a recommencement of the production tests	Investigating the results of the Second Onshore Gas Hydrate Production Test	Investigation of specific issues in offshore wells
4.5 Issues of the deep water production tests targeting the conventional oil and gas reservoirs	Under investigation	Investigation and provision of specific issues in offshore wells
5 Relevance environment on the seafloor		
5.1 Surveillance systems of gas leakage around subsea wellhead in the production test	Partly implemented in the METI/MITI Exploratory Test Wells	Investigation of the specific equipments and implementation structure in offshore wells
5.2 Broader area inquiry systems of environment	Under researching	Investigation of the specific implementation structure

Remarks MH: methane hydrate, ESP: electrical submersible pump

10. Predominant Research and Test Facilities

10.1 Improved PTCS

The PTCS (pressure temperature core sampler) utilized in retrieving the core samples is the sampling device developed in the special research “Methane Hydrate Development Technology” (FY 1995 - 2000), which is technology unique to our country and that enables core recovery while maintaining formation pressures and temperatures. The MITI Exploratory Test Wells “Nankai Trough” contributed to the discovery of pore-filling methane hydrate-bearing layers. After some improvements were made, it realized a core recovery factor of 80% and a success rate of pressure retention of 90% in the METI Exploratory Test Wells “Tokai-oki to Kumano-nada.”

Table 10-1 Recovery factors of the PTCS

	Number of Corings	Core Recovery	Pressure-holded	Temperature-holded
METI Exploratory Test Wells “Tokai-oki to Kumano-nada”	82 (6 wells)	79% (161.3m/203.5m)	90%	93%
MITI Exploratory Test Wells “Nankai Trough”	12	47% (16.9m/36.0m)	50%	92%

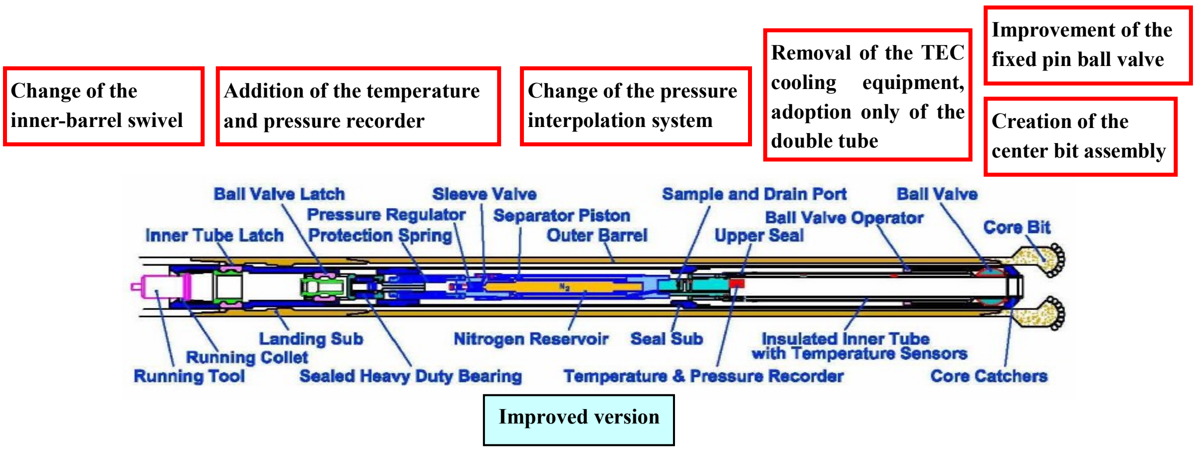


Figure 10-1 Improved version of PTCS

10.2 Laboratory Facilities of Core Testing

The predominant testing equipment created for various core tests in the Research Group for Production Method and Modeling are listed in Table 10-2.

Table 10-2 List of laboratory facilities of core testing

Fiscal Year	Facility Name	Intended Purposes and Characteristics of the Facility
Analyses of the Basic Physical Property of MH Sedimentary Layers		
2002	Equipment of core sample preparations for mimicking MH sediments	Equipment of making the MH sediment samples of which pores are filled with methane hydrate at aimed saturation by high-pressure methane penetrating through the water content-controlled sand samples. The sample size is larger than φ50/65mm x 150mm.
2002	Equipment of decomposition heat and specific heat measurements for MH cores	Equipment of specific heat and decomposition heat measurements under high pressure for methane hydrate-bearing sandy cores and muddy cores.
2004	Equipment of thermal conductivity measurement for MH cores	Equipment of thermal conductivity measurements for mimic MH samples and natural core samples
2002	Equipment of compressive strength measurement for MH cores	Equipment of tri-axial compressive strength measurements for MH sediments at the in-situ conditions
2002	Equipment of 3-dimensional analyses for framework structure of MH sediments (Microfocus X-ray CT instrument)	Equipment of 3-dimensionally identifying and visualizing pores, sands, hydrates and waters in MH core samples, and analyzing their distributions. It is also used for nondestructive measurements of porosities and saturations.
2003	Equipment of gas permeability and hydraulic conductivity measurements	Equipment of measuring permeabilities at the in-situ conditions, and analyzing the influences of MH saturations etc.
2004	Equipment of permeability measurements for muddy sediments	Equipment of water permeability measurements at the in-situ conditions by the steady method for MH muddy sediments. It is also capable of measurements of shrinkage changes to the head pressure for sediments.
2005	Equipment of capillary pressure measurements for sediments	Loading equipment of re-enacting the in-situ stress of sediments. Equipment of sediments transmembrane pressure measurements fitting up the pressure cell etc. It is capable of gas seal capacity etc. evaluations of sedimentary layers.
2005	Equipment of pore diameter/water permeability measurements at the same time for MH sediments	Equipment of analyzing the relations between pore diameter and permeability of MH sandy sediments. It analyzes permeabilities by water-saturated pore size distributions. It is also used for comparative investigations to well log data.
Analyses of the production behaviors and the production properties		
2002	Facility of explosion protected high pressure experiments	The laboratory for making the mimic MH sediments using high pressure methane and the core decomposition experiments fitting up the enforced ventilation and the air-conditioning equipment (5˚C -10˚C). Compliant to the high pressure gas safety law.
2002	Equipment of dissociation behavior analyses for MH cores	Experimental equipment of dissociation analyses for the depressurization method, the borehole thermal stimulation method and the hot water injection method at the in-situ conditions. Withstand pressure 25MPa, sample size 50mm x 300mm.
2003	Equipment of dissociation behavior observations for MH cores (high speed X-ray CT)	Equipment of real-time visualizing and analyzing the growth and the shifting of the dissociation front at the in-situ conditions in MH sediments. The shifting phenomena can be modeled by recording the 3-dimensional CT images of sediments in high speed.

2003	Equipment of consolidation and permeability measurements for cores from the METI/MITI Exploratory Test Wells	Equipment of permeability change measurements due to consolidation at the in-situ conditions.
2005	Experimental equipment of flushing and sanding phenomena evaluations	Equipment of experimentally observing sanding phenomena causing the production damages at the in-situ conditions. It observes both of flushing and sanding in time sequence.
2006	Equipment of analyzing fine-grained sand flow and accumulation in pores	Equipment of experimentally analyzing the flow and accumulation behaviors of silty sands accompanied with production under the in-situ condition, and evaluating the production damages caused by skin formations.
2004	Test equipment of the hot water injection method evaluation	Dissociation experimental equipment of evaluating the productivity of the hot water injection method at the in-situ condition.
2004	Equipment of inhibitor injection and dissociation experiments	Dissociation experimental equipment of evaluating the productivity of the inhibitor injection method at the in-situ conditions.
2005	Equipment of steam injection and dissociation experiments	Dissociation experimental equipment of evaluating the productivity of the steam injection method at the in-situ conditions.
2002	Equipment of fluid flow property simulator	Basic equipment of water and gas permeability measurements under various flow conditions. Equipment of fluid flow observations for developing the permeability property calculation module.
2002	Equipment of consolidation property simulator tests	Equipment of analyzing the consolidation property of MH sandy sediments and alternating beds of sand and mud. Equipment of mechanical tests for creating the consolidation property calculation module.

Remarks) MH: methane hydrate

10.3 Research Facilities Related to the Offshore Environment Survey

The main facilities used in the research of the Research Group for Environment Impact are listed in Table 10-3.

Table 10-3 Primary facilities used in Research Group for Environment Impact research

Fiscal Year	Facility Name	Intended Purposes and Characteristics of the Facility
2003	Database hardware (Web/Apl server/ GIS server/DB server/peripheral devices/device installation)	The response system to the inquiries from the unspecified number of individuals and organizations with having stored the achievements of the Research Group for Environment Impact.
2003	Acoustic Doppler velocimeter Current Profiler	Used in measurements of current direction and velocity in the marine environmental surveillance.
2003	Sediment trap	Used in measurements of flux of sedimented particles in the marine environmental surveillance.
2003	Mooring system (releaser system attached)	Used in installation and recovery of the measurement devices such as the current profiler, the sediment trap etc. in the marine environmental surveillance.
2006	Benthic chamber	Used in measurements of methane flux etc. in the marine environmental surveillance.
2003	High pressure triaxial compression test apparatus for low-temperature condition	Soil test apparatus of taking in the seafloor ground physical properties.

11. Others

11.1 Cooperation and Collaborations with Foreign Countries

Relevant cooperation and collaborations with foreign countries are as follows.

(1) The First Onshore Methane Hydrate Production Test (2002) The First Onshore Methane Hydrate Production Test executed in the Mackenzie Delta, Canada in cooperation and collaboration with Canada, USA, Germany and India.

(2) The Second Onshore Methane Hydrate Production Test (2007 and 2008) The Second Onshore Methane Hydrate Production Test was executed in the Mackenzie Delta, Canada in cooperation and collaboration with Canada.

(3) Joint Industry Program "Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Application for Safe Exploration and Production Activity" (2001 -)

The purpose of this program is to characterize the natural gas hydrate-bearing sediments in deep water areas off the Gulf of Mexico. In particular, the basic physical properties of methane hydrate-bearing layers that will become necessary for the safe exploitation and operations in conventional oil and gas fields should be obtained, and furthermore, necessary studies for constructing the reservoir model will be carried out. Participating organizations and industries are listedin Table 11-1.

Table 11-1 Organizations and Industries participating in the Joint Industry Program

Japan Oil, Gas and Metals National Corporation	Chevron Energy Technology Company
Schlumberger Technology Corporation	Reliance Industries Limited, Oil and Gas Division (private company in India)
ConocoPhillips Inc.	
Halliburton Company	Korean National Oil Company (KNOC) (participated from October in 2007)
Minerals Management Service (MMS)	
TOTAL E&P USA, INC	STATOILHYDRO (participated from March in 2008)

(4) International project on the comparison of production simulators

This international project was sponsored by the research institute of the US Department of Energy and the US Geological Survey of the Department of the Interior, where Japan, Canada and the US have participated. At present, the simulator in Japan has prerogatives to the other simulators (refer to the section 7. The Production Simulator).

(5) Collaboration between Japan and India

The JOGMEC contracted the MOU with the Indian Ministry of Petroleum and Natural Gas-

Directorate General of Hydrocarbons (DGH) in February 2007. The exchange of information on the researches of methane hydrate has been undertaken between both countries.

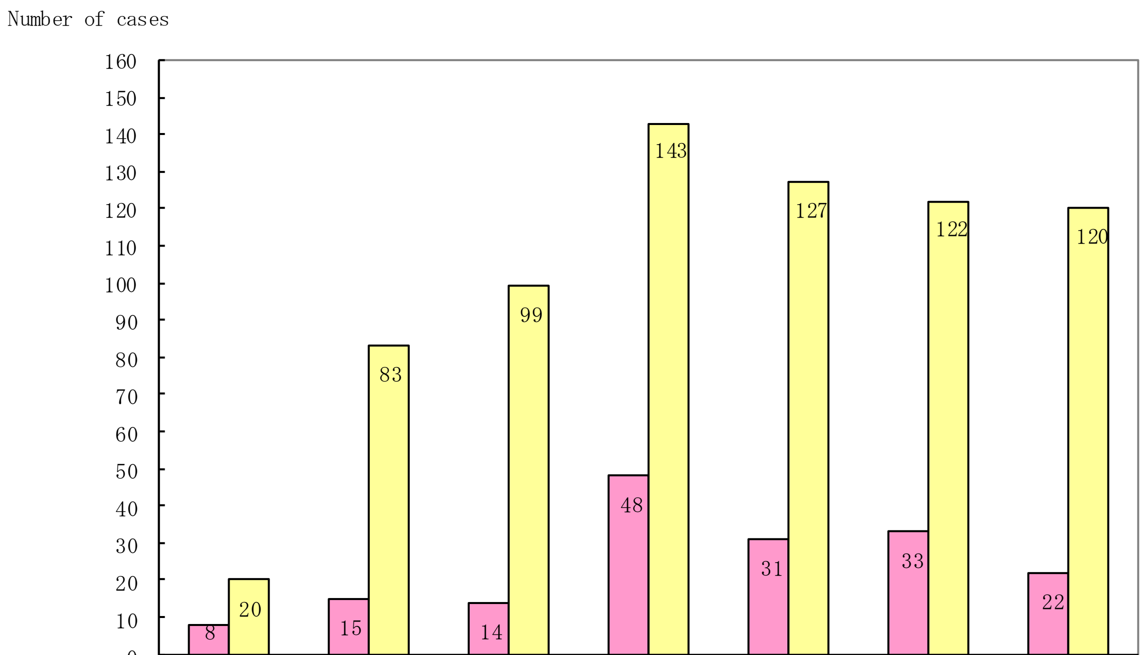
(6) The collaborative researches between Japan and the US

The US Department of Energy and the METI agreed the collaborative researches in June 2008. An onshore production test is planned in Alaska as a joint implementation.

11.2 Conference Presentations and Publications

Conference presentations and publications in Phase 1 are listed in Table 11-2.

Table 11-2 Conference presentations and publications in Phase 1 (as at the end of July 2008)



	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008
Papers publications	8	15	14	48	31	33	22
Conference presentations	20	83	99	143	127	122	120

*Number as at the end of July in FY 2008

11.3 Patents

Table 11-3 is available only in Japanese.

Table 11-3 フェーズ１の研究で取得した特許一覧

出願番号・公開番号	出願日・公開日	出願人	発明者	発明の名称
特許出願 2003-289857 特許公開 2005-60957 <生産手法開発＞	2003 年 8 月 8 日 2005 年 3 月 10 日	秋田大学長 外1名	佐々木 久郎 外3名	メタンハイドレート堆積層からの主にメタンガスの生産方法、及び模擬ハイドレート堆積層モデルを用いる主にメタンガスの生産特性を測定する方法
特許出願 2003-379600 特許公開 2005-139825 <資源量評価＞	2003 年 11 月 10 日 2005 年 6 月 2 日	鹿島建設株式会社	三浦 悟 外4名	ガスハイドレートの生産方法及びシステム
特許出願 2004-20524 特許公開 2005-213824 <生産手法開発＞	2004 年 1 月 28 日 2005 年 8 月 11 日	秋田大学長 外1名	佐々木 久郎 外5名	メタンハイドレート堆積層からの天然ガス生産設備と発電設備を具備する統合設備
特許出願 2004-185103 特許公開 2006-10400 <生産手法開発＞	2004 年 6 月 23 日 2006 年 1 月 12 日	三菱重工業株式会社	橋本 秀昭 外1名	加圧試験装置
特許出願 2004-219219 特許公開 2006-37518 <生産手法開発＞	2004 年 7 月 27 日 2006 年 2 月 9 日	三菱重工業株式会社	有川 究 外2名	ガスハイドレードの採集方法、ガスハイドレード採集システム
特許出願 2004-229000 特許公開 2006-45128 <生産手法開発＞	2004 年 8 月 5 日 2006 年 2 月 16 日	独立行政法人産業技術総合研究所	羽田 博憲 外6名	メタンハイドレートの分解方法及び分解装置
特許出願 2004-280861 特許公開 2006-96779 <生産手法開発＞	2004 年 9 月 28 日 2006 年 4 月 13 日	独立行政法人産業技術総合研究所	羽田 博憲 外6名	窒素によるメタンハイドレートの分解方法及び分解装置
特許出願 2004-327728 特許公開 2006-138706 ＜資源量評価＞	2004 年 11 月 11 日 2006 年 6 月 1 日	三井造船株式会社	星島 一輝 外3名	ハイドレート層の層厚推定方法
特願 2005-8938 特開 2006-194822 ＜環境影響評価＞	2005 年 1 月 17 日 2006 年 7 月 27 日	応用地質株式会社	内山 成和 外2名	加速度センサを用いる地盤等の変位モニタリング方法
特願 2005-100353 特開 2006-284184 ＜環境影響評価＞	2005 年 3 月 31 日 2006 年 10 月 19 日	石川島検査計測株式会社 国立大学法人山口大学	森田 幹 外3名	溶存可燃性ガス濃度の測定方法及び装置
特許出願 2005-166253 特許公開 2006-336435 <生産手法開発＞	2005 年 6 月 6 日 2006 年 12 月 14 日	独立行政法人産業技術総合研究所	川村 太郎 外7名	温度勾配付加型コアホルダー装置及びこれを用いた成分産出挙動時間変化測定方法
特許出願 2005-317536 特許公開 2007-120257 <生産手法開発＞	2005 年 10 月 31 日 2007 年 5 月 17 日	独立行政法人産業技術総合研究所	坂本 靖英 外7名	熱水と窒素の同時圧入によるメタンハイドレート貯留層の浸透性改善および分解促進技術
特許出願 2006-51099 特許公開 2006-267096 ＜資源量評価＞	2006 年 2 月 27 日 2006 年 10 月 5 日	シュルンベルジュ ホールディングス リミテッド	福原 政文 外2名	ダウンホール内の熱特性を測定するシステム及び方法
特許出願 2006-136601 特許公開 2007-308891 <生産手法開発＞	2006 年 5 月 16 日 2007 年 11 月 29 日	独立行政法人産業技術総合研究所	皆川 秀紀 外4名	メタン採取方法
特許出願 2007-196650 特許公開--- ＜資源量評価＞	2007 年 7 月 27 日 (出願中・未公開)	日本海洋掘削株式会社	中村 雅洋 外 3 名	メタンハイドレートの分解促進およびメタンガス採取システム

11.4 Public Offering Research Proposals

Business projects from the public offering research proposals were carried out from FY 2002 to 2005 for the purpose of applying these achievements to present research by broadly soliciting and realizing the proposals of the inventive and innovative technical issues regarding the technical issues related to each research field of the Resources Assessment, the Production Method and Modeling, and the Environment Impact in the Research Consortium for Methane Hydrate Resources in Japan from applicants other than the Research Consortium for Methane Hydrate Resources. The numbers of applications was 6 in 2002, 5 in 2003, 4 in 2004, and 4 in 2005.

11.5 Reinforcement of Internal Cooperation, Dissemination of Research Results, and Publicity

1) Reinforcement of Internal Cooperation

(a) The Steering Committee Meeting

The project leader, group and subgroup leaders of the Research Group for Resources Assessment, the Research Group for Production Method and Modeling, and the Research Group for Environment Impact, and the group leader of the Secretariat for Research Consortium for Methane Hydrate Resources in Japan convene the steering committee meeting, which has confirmed the current research status of the Research Consortium for Methane Hydrate Resources in Japan and investigated the direction it should take. Steering committee meetings have been held a total of 46 times (as at the end of July 2008).

(b) Workshops

During the initial phase of the Research Consortium for Methane Hydrate Resources in Japan in 2002-2004, cross-sectional workshops have been held 8 times inside the Research Consortium for Methane Hydrate Resources in Japan in order to deepen exchanges and share fundamental knowledge.

(c) Working groups and the task force

12 workings (WG) and one task force (TF) were founded (Table 11-4), and cross-sectional research themes have been scrutinized beyond the groups.

Table 11-4 Already launched working groups (WG) and task forces (TF)

WG Name	Installation Period
The Marine Survey WG	June 2002 - May 2007
The Core Test Investigation WG	April 2004 - May 2007
The Second Onshore Methane Hydrate Production Test WG	October 2003 - May 2004
The Production Test Analysis WG	June 2002 - September 2003
The Offshore Production Test Preparation WG (First)	September 2003 - May 2004
The Artificial Methane Hydrate Sediment Core WG	March 2003 - May 2007
The MH Resource Field Selection WG	May 2007 -
The Economic Potential Deliberation WG	May 2007 -
The Phase 2 Plan Preparation WG	May 2007 -
The Offshore Production Test Preparation WG (Second)	May 2007 -
The Environmental Impact Macro Risk Evaluation WG	May 2007 -
The Onshore Production Test Analysis WG	May 2008 - March 2009 (plan)
The TF of Production Test Planning	May 2004 -

(d) Interim meeting of accomplishment reporting

In order to share the achievements derived from each research group among the members of the Research Consortium for Methane Hydrate Resources in Japan, interim meetings to report accomplishments of the previous fiscal year have been held 7 times from FY 2002 to FY 2008.

(e) Information sharing

The group wares and mail lists were created for the exclusive use of members of the Research Consortium for Methane Hydrate Resources in Japan, and they shared information inside the Research Consortium for Methane Hydrate Resources in Japan.

2) Dissemination of Research Results and Publicity

(a) The data and samples provided to the mass media and education-related organizations

Data and samples such as photos, figures and so on have been provided in 252 cases to the mass media and education-related organizations (as at the end of July in FY 2008).

Table 11-5 Data and samples provided to the mass media and education-related organizations

Fiscal Year	Mass Media	Education-Related	Others*	Total
FY 2002	10	3	9	22
FY 2003	18	7	13	38
FY 2004	16	10	13	39
FY 2005	9	1	17	27
FY 2006	20	6	25	51
FY 2007	10	10	28	48
FY 2008 (as of end of July)	16	4	7	27
Total	99	41	112	252

*Remarks) Data and samples provided to home pages of companies and organizations, company newsletters, and advertisements

(b) Public meeting to report accomplishments

In order to open the achievements of the Research Consortium for Methane Hydrate Resources in Japan to the public, public meetings reporting the accomplishments of the previous fiscal year have been held 7 times from FY 2002 to FY 2008.

(c) Creation of a brochure of the Research Consortium for Methane Hydrate Resources in Japan

A brochure concerning the Research Consortium for Methane Hydrate Resources in Japan was created and distributed.

(d) Creations of the documentary films and the explanatory films

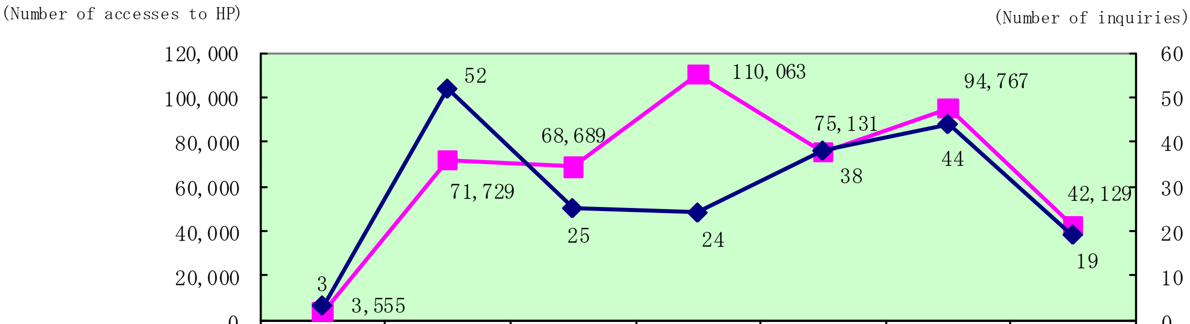
In addition, the following records and explanatory films were created and posted on the home page. They were also delivered as DVD or in VHS format to education-related institutes.

- Documentary: “Mallik 2002 Gas Hydrate Research Well Program” (Japanese and English)
- Explanatory film: “Methane Hydrate, Growing Prospective Resources for the Next Generation”
- Explanatory film: “MH21, the Research Consortium for Methane Hydrate Resources in Japan”
- Explanatory film: “MH21, the research achievements of Phase 1 (tentative)” (scheduled for completion in fall 2008)

(e) Home page

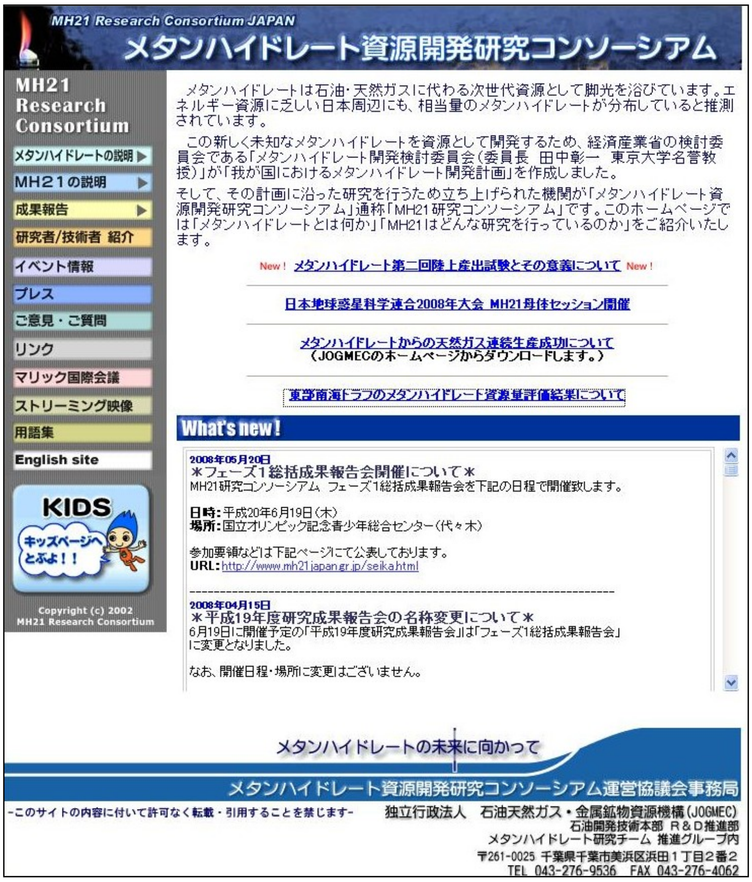
As part of the publicity for the Research Consortium for Methane Hydrate Resources in Japan, a home page titled, “The Research Consortium for Methane Hydrate Resources in Japan” was created (Japanese and English) and opened to the public in January 2003. A total of 466,063 hits have been recorded since January 2003 (as at the end of July 2008). In addition, an “Inquiry Corner” was built into the home page, which by the end of July FY2008, had responded to 205 inquiries.

Table 11-6　Year-on-year numbers of accesses and inquiries to the MH21 home page



	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008
Number of accesses to HP	3, 555	71, 729	68, 689	110, 063	75, 131	94, 767	42, 129
Number of inquiries	3	52	25	24	38	44	19

*Number as at the end of July in FY 2008



http://www.mh21japan.gr.jp/

Figure 11-1　Home page of the Research Consortium for Methane Hydrate Resources in Japan

12. English Abbreviations Cited

- JOGMEC: Japan Oil, Gas and Metals National Corporation ⇒ (独)石油天然ガス・金属鉱物資源機構
- AIST: National Institute of Advanced Industrial Science and Technology ⇒ (独)産業技術総合研究所
- ENAA: Engineering Advancement Association of Japan ⇒ (財)エンジニアリング振興協会
- BSR: Bottom Simulating Reflector ⇒ 海底擬似反射面
- LWD: Logging While Drilling ⇒ 掘削同時検層
- SMI: Sulfate Methane Interface ⇒ 硫酸塩-メタン境界
- IRR: Internal Rate of Return ⇒ 内部利益率
- SPAR ⇒ 浮遊式生産システムのひとつ
- NPV: Net Present Value ⇒ 正味現在価値
- CDOG: Comprehensive Deepwater Oil and Gas Blowout Model
- GSC: Geological Survey of Canada ⇒ カナダ地質調査所
- MDT: Modular Formation Dynamics Tester ⇒ Schlumberger社登録商標
- NRCan: Natural Resources Canada ⇒ カナダ天然資源省
- DTS: Distributed Temperature Sensor
- NETL: National Energy Technology Laboratory ⇒ 米国エネルギー省研究機関
- USGS: United States Geological Survey ⇒ 米国内務省地質調査所
- TOC: Total Organic Carbon ⇒ 全有機炭素量
- COTHMA: Coupled thermo-hydro-mechanical analysis with dissociation and formation of methane hydrate in deformation of multiphase porous media ⇒ メタンハイドレート層圧密・変形解析シミュレータ
- EDS: Energy Dispersive X-ray Spectrometer ⇒ エネルギー分散型X線分析装置
- ROV: Remotely Operated Vehicle ⇒ 有索無人潜水機
- METSセンサー: 溶存メタンセンサー（Franatech社登録商標）
- HSE: Health, Safety & Environment ⇒ 労働安全衛生及び環境
- PTCS: Pressure Temperature Core Sampler ⇒ 圧力・温度保持コアサンプラー
- DGH: Directorate General of Hydrocarbons ⇒ インド石油天然ガス省石油ガス総局
- MOU: Memorandum of Understanding ⇒ 研究交流の覚書